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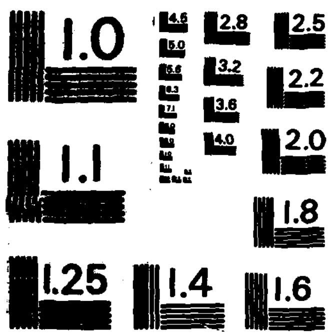

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Alternatives for Disposal of Depleted Uranium Waste

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NOVEMBER 1985

FINAL REPORT FOR PERIOD OCTOBER 1984–AUGUST 1985

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FOR THE COMMANDER

Joe A. Farmer

JOE A. FARMER
Chief, Operations Division

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Large quantities of depleted uranium wastes are generated at Eglin AFB each year due to testing of armor penetrating munitions. The majority of this waste consists of sand contaminated with small amounts of depleted uranium. In this study various alternatives for disposal were examined in detail including: disposal at DOE facilities, disposal at commercial facilities, on-site disposal, recycling to industry, inerting/stabilization, and volume reduction. Each alternative was evaluated according to technological status/risk, economic considerations, environmental impact, and commitment of resources.

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PREFACE

This program was conducted by Westinghouse Hittman Nuclear Incorporated, 9151 Rumsey Road, Columbia, Maryland 21045, under contract F08635-84-C-0333 with the Environics Branch of the Air Force Armament Laboratory, Eglin Air Force Base, Florida. Dr. M. Patrick and Dr. J. Cornette managed the program for the Armament Laboratory. The program was conducted during the period October 1984 to August 1985.

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SUMMARY

As much as 8100 cubic feet of radioactive waste is generated at the Eglin Air Force Base in a year. This waste is generated in the testing of armor penetrators and consists primarily of sand contaminated by depleted uranium. The armor penetrators are fired into a sand target butt. The core of the target is removed after firing about 25,000 penetrators, and the penetrator fragments are removed by sieving. The sand is then returned to the target. After three or four firing cycles, the entire butt is removed, placed in about 1,100 55-gallon steel drums, and replaced with new sand.

Up until 1983, the drums containing the separated penetrator fragments and sand were disposed of at commercial low-level radioactive waste disposal sites. The waste generated since that time and the waste generated from the three changes of the target butt are stored at the test site at Eglin AFB.

The waste in storage consists of 3500 55-gallon drums of contaminated sand, 58 18-gallon drums of penetrator fragments and sand, and 80 55-gallon drums containing high efficiency particulate filters (HEPA). In addition, there are a number of armor plates and concrete blocks with localized depleted uranium contamination.

The depleted uranium concentrations of the contaminated sand exceed the allowable limits for on-site disposal. This material must be disposed of at a commercial low-level radioactive waste disposal site. Because the contaminated sand is

wet, it must be dried or solidified and repackaged before it can be shipped to a disposal site.

Drying with a rotary drier is considered to be the best method for processing the material. In addition to drying, the rotary drum should convert small pieces of uranium metal to a non-pyrophoric form.

The cost of processing, packaging, transportation, and disposal of the 3500 drums of contaminated sand is estimated to be about $1,280,000. About $315,000 of this amount is the cost of replacing the drums and disposing of the existing drums. If the material can be made non-pyrophoric by processing in the rotary dryer, it can then be shipped as low specific activity (L.S.A.) radioactive material in the existing drums that can be qualified as strong tight industrial containers. If half of the existing drums can be reused, the savings will be an estimated $132,000. An additional $124,000 can potentially be saved by shipping the material by rail rather than truck.

The 58 drums containing depleted uranium penetrator fragments and sand should be dried and repackaged in drums inerted with argon gas. This material should be offered to manufacturers of depleted uranium products. The feasibility of recycling depleted uranium products has been previously demonstrated. Even though recycling of penetrator fragments does little to reduce the quantities of waste to be disposed, depleted uranium is a national resource which should be conserved and recycled to the maximum extent possible.

The drums containing HEPA filters can be shipped with the drums of contaminated sand. The depleted uranium contamination on the armor plates and concrete blocks should be

removed and the residue packaged for disposal with the other waste.

The cost estimates for the disposal of the current waste inventory are based on disposal at the commercial disposal site at Beatty, Nevada. At the present time, Eglin AFB does not have an allocation for disposal of waste at the facility at Barnwell, S.C. The lower burial costs at the Beatty facility nearly offset the higher transportation costs.

The Low-Level Radioactive Waste Policy Act of 1980 is scheduled to go into effect on January 1, 1986. This act calls for the establishment of compacts to handle low-level radioactive waste on a regional basis. When the compacts are approved by the U.S. Congress, the compacts will have the right to exclude wastes from generators outside the compact. There is a great deal of uncertainty relative to implementation of the Waste Policy Act and the availability of future burial space.

A Memorandum of Understanding between the Department of Defense and the Department of Energy allows the DOD to use DOE disposal sites in the event commercial sites are not available through no fault of DOD. This agreement does require the DOD contractors and activities to have contingency plans for the disposal of waste at DOE facilities. No approved contingency plan exists at the present time. This report contains guidelines for the preparation of contingency plans and a model contingency plan for Eglin AFB. Due to the uncertainties relative to the availability of future disposal space, a contingency plan for Eglin AFB should be formally implemented as soon as possible.

A detailed evaluation was made of on-site disposal of depleted uranium waste at Eglin AFB. Improved shallow land burial or an engineered disposal facility would be required to meet the requirements of 10CFR61 due to the hydrologic, geologic, and climatic conditions at the site. The cost of licensing, constructing and operating such facilities was found to be greater (i.e., $40 to $80 per cubic feet) than the cost of disposal at commercial facilities (i.e., $28 to $33 per cubic feet). A facility capable of disposing of all of the waste on-site cannot be justified.

The U.S. Nuclear Regulatory Commission permits on-site disposal of radioactive material having low-levels of contamination under 10 CFR 20.302. In the case of depleted uranium, the limits are 3000 picrocuries per gram for insoluble material and 1000 picocuries per gram for soluble material. Studies indicate that the hydrologic conditions at the Eglin AFB site will permit the disposal of contaminated material at these concentrations by burial at the test site. A proposed license application to permit on-site disposal is included in this report. The cost of on-site disposal of materials having concentrations within the limits noted above is $16.35 per cubic foot and considerably less than off-site disposal at commercial facilities.

The Air Force must take action to reduce the quantities of waste being produced and the quantities requiring off-site disposal. The cost of disposing of low-level radioactive waste has increased significantly over the past few years. Most generators have instituted volume reduction programs, and the reduced quantities of waste will cause the disposal cost to increase even more. The quantity of waste could be reduced to less than 300 cubic feet per year by firing into a water target. This would require the design and construction

of an entirely new firing range. The volume of waste requiring off-site disposal can potentially be reduced by segregating the target butt to reduce the quantity of sand becoming contaminated during the firing cycle. The current practice of removing the penetrators from the sand and reusing the sand creates additional waste due to mixing with uncontaminated sand. Selective removal and disposal of the contaminated sand from the central core should reduce the quantities of contaminated sand that must be disposed off-site.

The sand in the balance of the target butt will become contaminated due to airborne activity within the building housing the target butt. The objective would be to minimize the rate of contamination and to remove the sand before it reaches limits for on-site disposal.

Because of the uncertainties relative to the availability of future disposal space, priority should be given to the disposal of the current inventory of contaminated sand as soon as possible. At the same time, the drums containing penetrator fragments should be offered to manufacturers of depleted uranium products to determine whether recycling is a viable long-term practice. The contingency plan should be filed as soon as possible to allow the use of DOE facilities in the event that commercial facilities are not available to accept the current waste inventory.

Amending the license to allow the on-site disposal of materials having low-levels of contamination has a lower priority, since the waste now being generated exceeds the limits for on-site disposal. This licensing action should go forth in parallel with the program for modifying the firing procedures and facilities to reduce the quantities of waste being generated.

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SECTION I

INTRODUCTION

1. BACKGROUND

The Air Force began testing depleted uranium munitions at Eglin AFB in the late 1960's. Early research efforts to capitalize on the high density and availability of depleted uranium as a raw material for the production of armor penetrators were directed toward the design and evaluation of 0.5 caliber and 20, 30 and 40 millimeter penetrators. This early work involved open air test firing of a few hundred penetrators, primiarly against armor targets. The wastes generated during these tests consisted of relatively small volumes of depleted uranium penetrators plus contaminated target materials and residues from the decontamination of the target materials. No difficulty was experienced in disposing of these wastes at commercial low-level radioactive material disposal sites.

The utility of depleted uranium as a munitions component has now become well established. This has resulted in increased production of depleted uranium wastes in research, development, test and evaluation programs. In addition, large quantities of wastes are generated in the large scale lot acceptance testing of the 30 millimeter penetrators in an enclosed target butt. The enclosed target butt is also used to conduct periodic quality assurance tests on depleted uranium munitions from the war reserves.

At the same time this additional waste was being produced, three of the six commercial disposal sites were closed. At the three remaining sites, the requirements for disposal

were made more stringent, and the prices for disposal were raised from less than $2.50 per cubic foot to more than $20.00 per cubic foot. At the Barnwell, South Carolina disposal site, allocations were imposed to limit the volume of waste that would be accepted. As a result of these actions, none of the depleted uranium waste has been shipped from Eglin Air Force Base since May 18, 1983.

2. WASTE GENERATION

The majority of the waste generated at Eglin AFB consists of sand contaminated with depleted uranium penetrator fragments. The target butt consists of about 300 cubic yards of sand into which depleted uranium armor piercing incendiary penetrators (API) and target practice (TP) are fired. The sand butt is housed in a building with controlled ventilation and the exhaust air passes through HEPA filters. The sand butt is dampened to reduce dust generation during firing. Figure 1 shows how the waste was generated and handled during the period January 5, 1979 through September 11, 1980. The various operations are described as follows:

a. During this period, there were four firing cycles in which 12,000 to 21,000 penetrators were fired into the sand butt. The number of penetrators that can be fired into the butt during a firing cycle is limited because a large number of penetrators in the butt will cause ricocheting. In the more recent firings, the number of penetrators per firing cycle has been increased to 25,000 or more.

b. After each cycle, the core of the sand butt is removed, and the penetrators are removed from the sand with a large mechanically driven sieve. The sieve has half-inch openings. The sand is dampened with water during the sieving

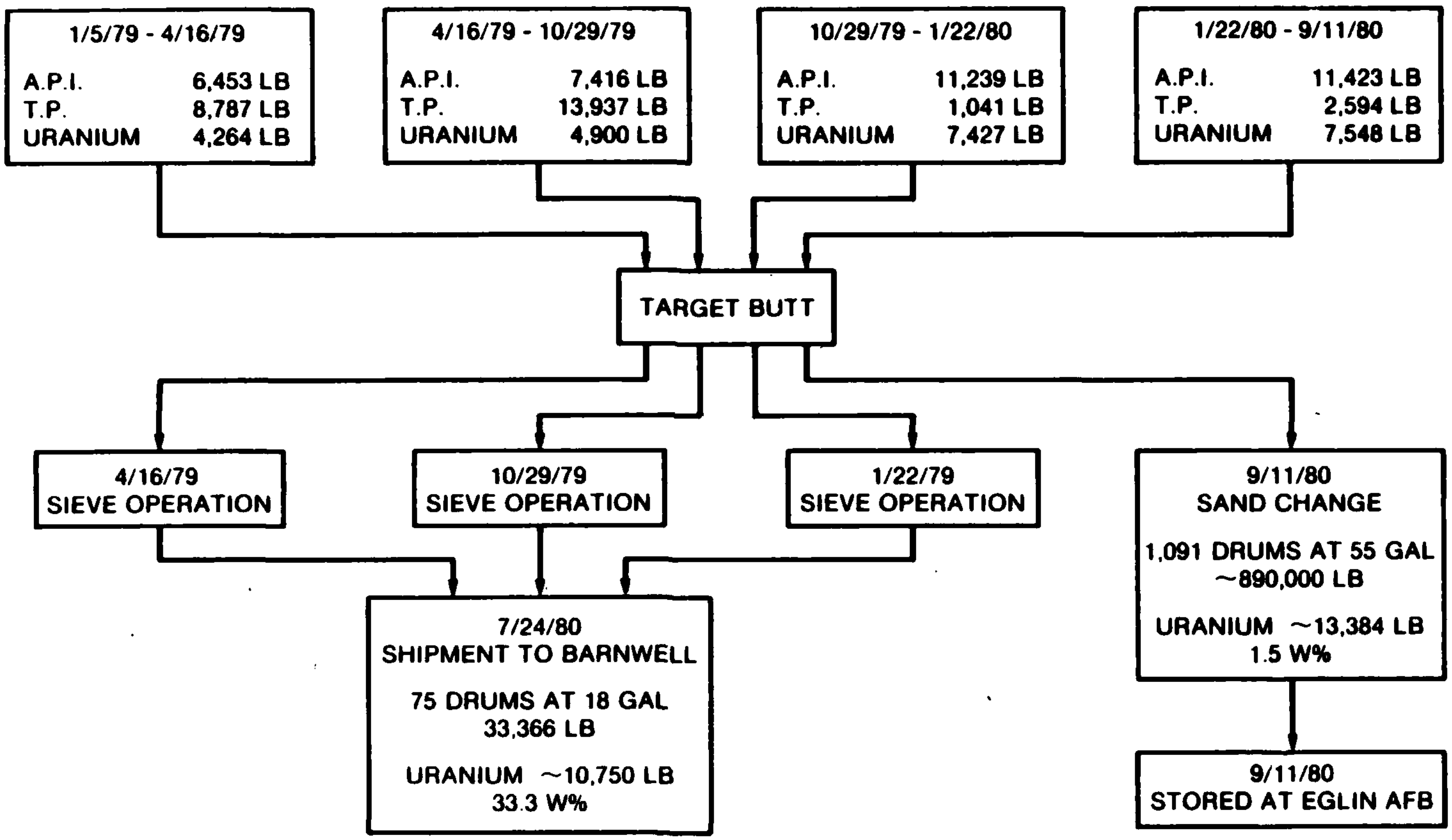

Figure 1. Depleted Uranium Sieving and Disposal Operations (Jan. 5, 1979 thru Sept. 11, 1980)

operation to reduce the possible spread of airborne contamination. The separated fragments and associated sand are placed in 16 to 18-gallon steel drums. The drums are either shipped to a disposal site or returned to manufacturers of depleted uranium products for recycling of the uranium. The drums containing both uranium penetrators and test penetrators have uranium concentrations of about 30-weight percent. Drums containing uranium pentrators have uranium concentrations as high as 60 percent. The sand passing through the sieve is returned to the target butt.

c. After three to four firing cycles, the entire sand butt is removed. The penetrators are removed by sieving, and the remaining sand is placed into 55-gallon steel drums. To date, there have been three sand butt changes, and all of the contaminated sand is stored at the test site at Eglin AFB in some 3,500 steel drums. The uranium content of these drums is generally in the range of 1 to 5 weight percent. However, a few samples have uranium concentrations as high as 20 percent. Figure 2 shows uranium concentrations of 29 samples randomly taken from the drums being filled during a sand change operation. The sand butt changes comprise the majority of waste volume requiring disposal.

3. PRESENT WASTE INVENTORY

The present inventory of waste now stored at the test site at Eglin AFB consists of the following:

Contaminated Sand (three sand butt changes)
3,500 - 55 gallon drums
Uranium Content 1 to 5 weight percent average
20 weight percent peak

			#160 30				
			#169 30				
			#210 29				
			#223 20	#57 38			
		#142 18	#374 21	#96 35			
	#1006 2	#195 14	#849 24	#232 37			
	#1015 2	#249 16	#861 25	#684 31	#45 40		
	#1052 4	#916 13	#935 27	#950 33	#71 48		#600 57
mg/gm	0 - 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70
W%	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7
nCi/gm	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21
VOL%	0 - 0.14	0.14 - 0.28	0.28 - 0.42	0.42 - 0.57	0.57 - 0.71	0.71 - 0.85	0.85 - 0.99
	#210 79		#242 97				
mg/g	70 - 80	80 - 90	90 - 100	100 - 110	110 - 120	120 - 130	130 - 140
W%	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14
nCi/gm	21 - 24	24 - 27	27 - 30	30 - 33	33 - 36	36 - 39	39 - 42
VOL%	0.99 - 1.13	1.13 - 1.27	1.27 - 1.42	1.42 - 1.56	1.56 - 1.70	1.70 - 1.84	1.84 - 1.98
			#13 168			#7 193	
			#14 165			#42 198	
mg/g	140 - 150	150 - 169	160 - 170	170 - 180	180 - 190	190 - 200	200 - 210
W%	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21
nCi/gm	42 - 45	45 - 48	48 - 51	51 - 54	54 - 57	57 - 60	60 - 63
VOL%	1.98 - 2.12	2.12 - 2.26	2.26 - 2.41	2.41 - 2.54	2.54 - 2.68	2.68 - 2.83	2.83 - 2.97

Figure 2. Uranium Concentrations of Random Sampled Drums

Penetrator Fragments (Sieve from Sand)

58 - 18-gallon drums

Uranium Content approximately 55 weight percent

HEPA Filters

80 - 55-gallon drums

Armor Plate and Concrete Blocks

Localized uranium contamination

In addition, the sand butt which was installed in May 1985 now contains some 50,000 penetrators, and the core will be removed in the near future to remove the penetrators.

4. DEPLETED URANIUM

Depleted uranium is the by-product of the enrichment of natural uranium for use in nuclear reactors. Natural uranium contains 0.72 percent U-235 and 99.275 percent U-238, with the balance comprised of trace quantities of the other uranium isotopes. In the natural state, uranium ore also contains equilibrium concentrations of daughter products generated by radioactive decay. As part of the enrichment process, the uranium is separated from the decay products and other impurities. Enrichment of the uranium is normally performed using the gaseous diffusion process to concentrate the U-235. The by-product of this process is depleted uranium which contains less than 0.5 percent U-235 and more than 99.5 percent U-238. Figure 3 shows the U-238 and U-235 decay series. Since the half life of uranium 238 is 4.5 by 10^9 years, and the half life of uranium 235 is 7.1 by 10^8 years, the buildup of decay products will be insignificant and will not be a factor in the disposal of depleted uranium.

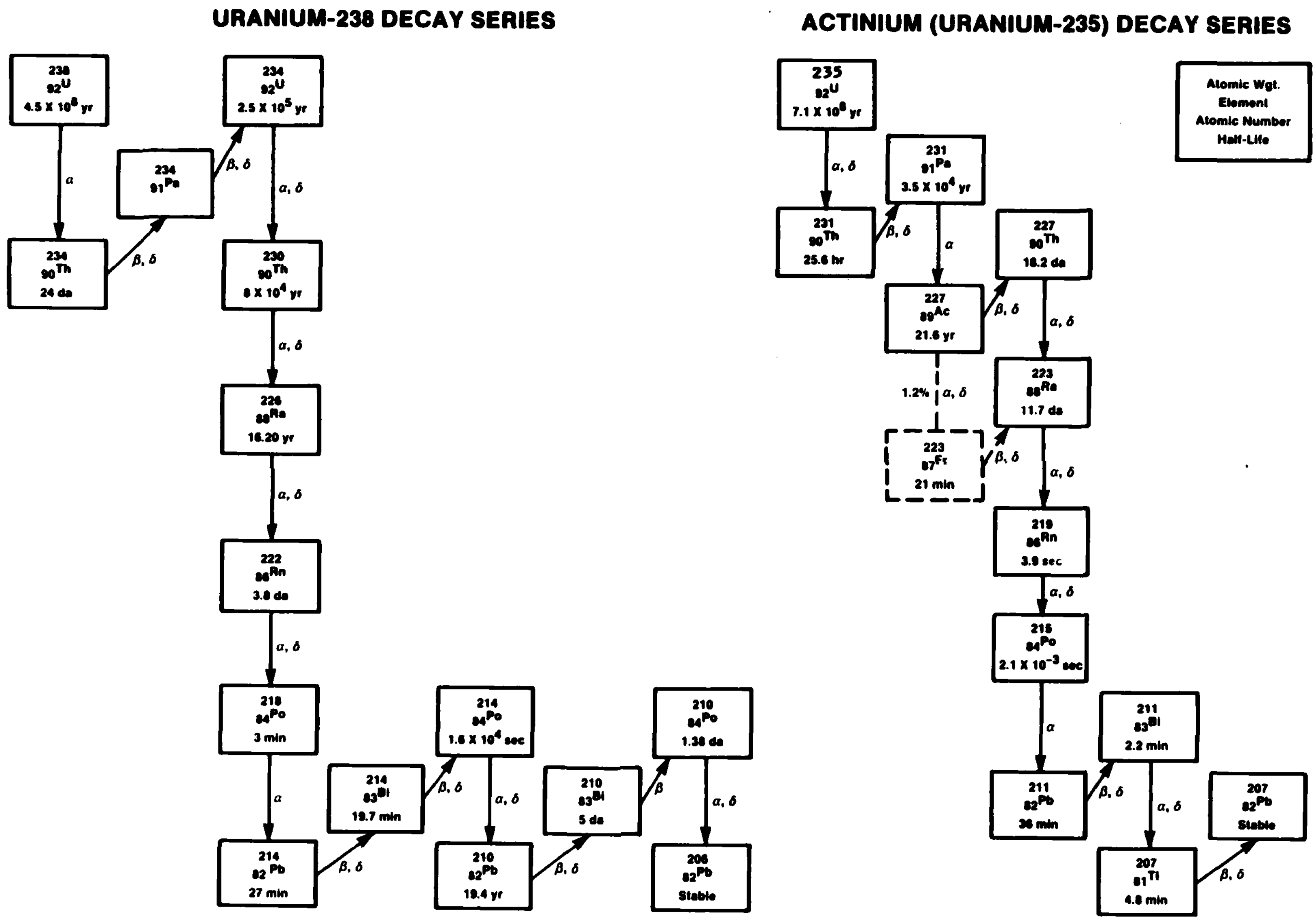

Figure 3. Uranium 238 and Uranium 235 Decay Series

The regulations governing the disposal of radioactive materials are based either on total activity expressed in curies or specific activity expressed in curies per gram or curies per cubic meter. Because of the long half life of uranium and other high atomic weight radioisotopes, specific activity is generally expressed in picocuries per gram or picocuries per milliliter. A picocurie is 10^{-12} curies. Table 1 shows the calculations to convert a depleted uranium oxide concentration of 1 percent on a weight basis to specific activity expressed in picocuries per gram. This calculation assumes that the uranium is all U-238 since it constitutes more than 99.5 percent of depleted uranium. The calculations assume the oxide is U_3O_8. However, the specific activity would be the same for UO_2 or uranium metal since the calculation is based on the mixture containing 1 percent uranium.

TABLE 1. SPECIFIC ACTIVITY OF DEPLETED URANIUM SAND MIXTURE

Gram mole U_3O_8 (3 x 238.1 + 8 + 16) (gms)	842.3
Grams uranium per gram mole (3x238.1) (gms)	714.3
Weight sand/uranium mixture @ 1% U (gms)	71,430
Gram moles per gram (1 ÷ 71,430)	1.4×10^{-5}
Atoms U-238 per gm ($1.4 \times 10^{-5} \times 3 \times 6.025 \times 10^{23}$)	2.53×10^{19}
Half life U-238	4.51×10^{9} yrs
	1.422×10^{17} sec.
Decay Constant, λ ($0.693 \div 1.422 \times 10^{17}$)	4.87×10^{-18}
Disintegrations per sec per gram ($2.53 \times 10^{19} \times 4.87 \times 10^{-18}$)	123.2
One Curie	3.7×10^{10} dis/sec
Uranium @ 1 percent	3.330×10^{-9} curies
	3,330 pCi per gm

Uranium 238 and depleted uranium are fertile materials and can be used in the production of plutonium and in breeder reactors. The quantities of depleted uranium produced in the enrichment of uranium far exceed the quantities that will be used in breeding of plutonium for the foreseeable future.

Depleted uranium is an extremely dense material with a density of 18.95 grams per cubic centimeter. The high density and availability of depleted uranium make it an ideal candidate for armor penetrating munitions. In addition, uranium metal is a pyrophoric material which can function as an incendiary agent after penetrating armor.

5. TOXICOLOGY OF URANIUM

Uranium is toxic to humans in two ways: first, as a nephrotoxin which chemically attacks the kidneys, and second, as a low specific activity radionuclide which is partially retained in specific body areas or organs.

a. Chemical Toxicity

Uranyl (UO_2^{+2}) compounds are very soluble, and uranyl carbonate complexes are also soluble; hence, uranium is very mobile at the pH found in bodily fluids (Ref. 1). Ninety-five percent of the uranium ultimately retained in the body is deposited in the bone. Excretion is mainly via the kidney, and the proximal tube is the critical organ in the kidney damaged by uranium. The earliest symptom of this damage is an increase in urinary catalase and albuminuria observed in both animals and humans. Experiments on volunteers and terminally ill patients utilized single injections of between 20-100 micrograms per kg body weight $UO_2(NO_3)_2$ to

induce these symptoms (Reference 2). This means that a 180-pound person would require a concentration intravenous dose of 6-7 mg $UO_2(NO_3)_2$ to begin affecting kidneys. Within 24 hours, 60 percent of a dose is excreted in the urine; 25 percent may ultimately be fixed in bone (Reference 3).

The main concern would be oral ingestion and the associated potential chemical toxicity. The fraction of uranium going from the gastro-intestinal tract into the blood is 0.01 (Reference 4). Consequently, a dose of from 600- to 700- mg would be required to reach the point where renal problems would be diagnosed in the above hypothetical 180-pound person. This would require 600- to 700- ppm U in a liter of ingested water.

b. Radiological Toxicity

Unlike chemical toxicity, radiological toxicity is enhanced by retention time of the alpha-particle-emitting uranium atom in a critical portion of the body. The most critical organ for radiological toxicity is the lung; the bone is next most critical. Lung exposure is caused by inhalation of uranium-bearing particles. However, lungs are not an exposure path for groundwater from buried waste. In this case, soluble uranium compounds will be ingested, and a certain portion of the uranium will be fixed in bone tissue. As high as 25 percent of the uranium carried in the blood-stream can eventually be depositied in bone tissue (Reference 3).

6. RADIOACTIVE MATERIALS LICENSE

Up until June 26, 1985, the depleted uranium at Eglin AFB is covered by the U.S. Nuclear Regulatory Commission Source Material License, Number SUB-992. Under this license,

the licensee may possess 70,000 kilograms of depleted uranium at any one time. The authorized uses are; receipt, storage, testing and evaluation of munitions containing depleted uranium. The Environics Branch of the Armament Laboratory was responsible for the license until early 1985. The responsibility for the license was recently transferred to the 3246th Test Wing, the group that directly performs the testing.

On June 26, 1985, the Nuclear Regulatory Commission granted a broad scope license to the U.S. Air Force. Under this license, the Air Force assumes the responsibility of licensing the various activities involving the use of nuclear and radioactive materials. This arrangement is similar to the licensing responsibility of an agreement state. With this transfer of licensing authority, the former Nuclear Regulatory Commission licenses have been redesignated as Air Force Permits. The license numbers remain the same, but the suffix of "AFP" is added to the number to designate that it is an Air Force Permit.

If the current Eglin AFB license is to be amended to allow on-site burial, the licensing action would be taken by the USAF Radioisotope Committee at Brooks AFB. However, the Radioisotope Committee might seek technical assistance from the Nuclear Regulatory Commission.

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SECTION II

IDENTIFICATION OF ALTERNATIVES

1. SCOPE

The work on this project was divided into two tasks. In the first task, all reasonable alternatives for the disposal of the waste generated at Eglin AFB were identified. This included collection of data relative to the quantities and types of waste being generated now and in the future. The regulations governing the handling, packaging, transportation, and disposal of depleted uranium waste were investigated for both off-site disposal and for disposal at Eglin AFB. A preliminary assessment was made of the hydrogeologic conditions at Eglin AFB with particular emphasis on the factors that would affect the disposal of depleted uranium at Eglin AFB. Conceptual designs were developed for on-site disposal of waste. The technical and economic aspects of on-site disposal were compared with off-site disposal at commercial burial sites or facilities operated by the Department of Energy. At the conclusion of the Task 1 effort, six alternatives were identified for detailed investigation in Task 2.

2. DISPOSAL AT DEPARTMENT OF ENERGY FACILITIES

a. Memorandum of Understanding

The Department of Energy (DOE) and its precursor, the Atomic Energy Commission, has the responsibility for the development, utilization and control of atomic energy for military and other purposes vital to common defense and security. The DOE is also responsible for processing and

utilization of source, byproduct and special nuclear materials in order to provide for common defense and security and to protect the health and safety of the public. As a matter of policy, it has been determined that radioactive waste generated by the Department of Defense (DOD) activities will be disposed of at commercial disposal sites if available. Disposal of DOD waste at Department of Energy facilities will be allowed only when commercial disposal sites are not available. This policy is contained in a Memorandum of Understanding between the Department of Energy and the Department of Defense which was renewed May 1, 1984 (Reference 5). The purpose of this Memorandum of Understanding is stated as follows:

> "The DOD and DOE objective is to assure the presence of suitable disposal sites for DOD and DOE contract related radioactive waste when commercial sites are not available because of events outside of DOD control."

The responsibilities of the two agencies in the implementation of this Memorandum of Understanding are summarized as follows:

(1) Department of Defense Reponsibilities

- Safety of radioactive waste packaging,

- Use of commercial disposal site unless unavailable due to circumstances beyond DOD control,

- Notification of DOE of potential disposal problems,

- Development of contingency plan for each contract,

- All costs for packaging, handling, transportation to and disposal at the designated DOE site.

(2) Department of Energy Responsibility

- Prompt review of DOD notifications of disposal problems,

- Provide appropriate waste disposal facilities for DOD and DOE contractors,

- Will not permit disposal at DOE sites if commercial disposal facilities are not available through fault of DOD,

- Assist DOD to the extent practical to resolve disposal problem (i.e., violations of packaging or shipping).

Representatives of the Department of Energy have reaffirmed the policy that the radioactive waste generated at Eglin AFB can be disposed of at DOE facilities only if commercial facilities are not available.

b. Status of Contingency Plans

The Memorandum of Understanding requires the Department of Defense to have contingency plans for the disposal of depleted uranium waste or low-level radioactive waste for each government activity or contract involving the use of

depleted uranium. The contingency plans must list the steps that will be taken in the event commercial disposal facilities become available.

In September, 1984 (Reference 6), draft contingency plans prepared by two contractors were submitted by the DOD to the DOE. Contingency plans had been submitted by contractors several years earlier, and the new plans were being submitted in compliance with the renewed Memorandum of Understanding. In November 1984 (Reference 7), the Department of Energy provided extensive comments on the contingency plans that had been submitted. In this transmittal, it was noted that the DOE comments that had been made on the original plans had not been incorporated. Under the Memorandum of Understanding, the DOE has the right of disapproval on the contingency plans. Accordingly, no approved contingency plans currently exist for the use of DOE facilities if commercial facilities are not available.

The Memorandum of Understanding refers to contingency plans for each contract which involves the use of depleted uranium. The Memorandum of Understanding does not explicitly require the government activities licensed and/or involved in the use of depleted uranium to submit contingency plans. In order not to impair the fulfillment of military missions, the military installations and other government activities involved in the use of depleted uranium should also have contingency plans for the disposal of waste generated at these installations. At the present time, no contingency plans for military installations are known to exist.

Section V of this report contains a detailed description of the items to be included in contingency plans, and Appendix D is an example of a contingency plan for Eglin AFB.

When the Memorandum of Understanding is renewed on July 1, 1987 (or earlier, if possible), the requirements for contingency plans for military installations as well as contractors should be clarified.

c. Cost of Disposal at DOE Facilities

Estimates were made of the cost to dispose of the current inventory of 3500 drums of waste at DOE facilities. The estimates were prepared to determine the potential impact if commercial sites were not available and to provide the data needed to compare disposal at DOE facilities with other alternatives. Table 2 is a summary showing the estimated cost for disposal of the current waste inventory at the DOE Nevada Test Site or at the DOE facility at Oak Ridge, Tennessee. These costs do not include drying and repackaging of the material and the cost of new containers. A further discussion of these items is contained in Section III of this report.

3. PACKAGING FOR TRANSPORATION AND DISPOSAL

Shipments of depleted uranium waste from Eglin AFB to the commercial burial facility at Barnwell, South Carolina were terminated in 1983 after questions arose relative to the proper packaging of depleted uranium waste. As previously discussed, the sand target butt is dampened to reduce the airborne activity. In addition, the sand is wetted during the sieving operation to reduce the possible inhalation of material by personnel performing the sieving operation. Accordingly, both the contaminated sand (55-gallon drums) and the sand and uranium penetrators (18-gallon drums) are damp when placed into the drums. The drums containing the waste

TABLE 2. DISPOSAL AT DEPARTMENT OF ENERGY FACILITIES

Transportation and Disposal Cost
(3500-Drum Inventory)

	Nevada Test Site	Oak Ridge, Tennessee
Mileage[1]	1990	526
Transportation Cost[2]	$238,200	$ 66,450
Burial Cost[3]	$ 65,625	$183,750[4]
Total Cost	$303,625	$250,200
Cost $/cf	$ 11.57	$ 9.53

[1] Mileage from Eglin AFB to the disposal facility.

[2] Based on one-way mileage commodity rates effective October 15, 1984, for low-level radioactive waste.

[3] Based on burial cost price schedules in effect on January 1, 1985.

[4] Based on burial cost book value of $7.00/cf.

have been stored in the open and have experienced some deterioration due to the weather. The majority of the waste must now be repackaged before it can be shipped either to a commercial disposal facility or to a DOE facility. The inventory of material is now quite large (>3,500 55-gallon drums), and the costs of disposing the waste have increased significantly over the past few years. Accordingly, the cost of disposing of the waste now represents a major project and will require a special allocation of funds for its accomplishment.

a. Department of Transportation Regulations

The Hazardous Materials Table contained in 49 CFR 172.101 lists Uranium Metal Pyrophoric as a radioactive material with identification number UN2979 and requiring Radioactive and Flammable Solid labels. The specific requirements for packaging are contained in 49 CFR 173.418 and no exceptions are allowed. Transportation in passenger carrying aircraft or railcar and in cargo aircraft is forbidden. On-deck or under-deck water shipments are allowed subject to the requirements of 176.63(b) and 176.63(c), respectively. These latter requirements are the same as those applied to high explosives.

The requirements for Authorized packaging-pyrophoric materials are specified in 49 CFR 173.418 and are summarized in Table 3. The referenced requirements of 49 CFR 173.24 and 49 CFR 173.465 are summarized in Tables 4 and 5.

Uranium metal in the form of cuttings, turnings, chips, grinder dust and fine grained powders is highly pyrophoric. Uranium metal powder used to fabricate components using powdered metallurgy processes is not considered pyrophoric if the particles are 15 microns or greater. Depleted uranium components including unclad penetrators with relatively sharp tips and threads are not considered pyrophoric and are routinely handled. Likewise, turnings having very thin sections will ignite and will oxidize that portion of the metal that is potentially pyrophoric. The apparent explanation is the very large amount of energy produced in the oxidation of uranium metal. The energy produced in oxidizing uranium metal is 835 kilocalories per gram mole of U_3O_8. This equates to 1.78 MBTU per pound of oxide. With thin sections of uranium metal, the heat is transferred to the

TABLE 3. DEPARTMENT OF TRANSPORTATION REGULATION
49 CFR 173.418

Authorized Packaging - Pyrophoric
Radioactive Materials

- Quantities not exceeding A_2 per package
- In solid form - not fissile
- Corrosion resistant receptacles
- Positive closures
- Free of water
- Made inert to prevent self-ignition:
  - Mixed with dry sand
  - Blended into concrete matrix
  - Receptacle filled with inert gas
- Meet requirements of
  - 49 CFR 173.24
  - 49 CFR 173.465

TABLE 4. DEPARTMENT OF TRANSPORTATION REGULATION
49 CFR 173.24

Standard Requirements All Packages

- No significant release to the environment
- No spontaneous increase in heat or pressure
- No significant chemical or galvanic reaction
- Closures to prevent inadvertent leakage

TABLE 5. DEPARTMENT OF TRANSPORTATION REGULATION
49 CFR 173.465

Type A Packaging Tests

- o Free drop from 4 feet
- o Compression five times weight of package
- o Penetration by 6 kg bar from 1 meter

adjacent metal causing it to heat to the ignition temperature before the energy can be dissipated. Ignition stops when the mass of the remaining metal can absorb the energy generated by the oxidation without reaching reaction temperatures. Thin sections of potentially pyrophoric uranium metal can be ignited by heating to as low as 400°F. Once the thin sections are heated and oxidized, the remaining metal should no longer be considered pyrophoric.

The problem with the existing regulations is that there is only one classification of uranium metal, and this classification considers all uranium metal to be pyrophoric. The current regulations do not specify what particle sizes are considered pyrophoric as is done in the case of zirconium and hafnium metals in 49 CFR 173.214.

An interpretation was informally requested from representatives of the Department of Transportation and the Nuclear Regulatory Commission relative to 49 CFR 173.418. In both cases, the opinion was that the uranium metal would still be classified as pyrophoric and as a flammable solid even after inerting with dry sand or cement. Accordingly, it would have to be shipped in Type A containers. It could not

be classified as Low Specific Activity material, L.S.A., and shipped in strong tight industrial containers. Contacts with individuals at National Laboratories handling depleted uranium indicate that materials inerted with cement and fabricated components are shipped as L.S.A. and are not labeled as a flammable solid.

There is a precedent in the DOT regulations for determining whether materials are pyrophoric by means of a test. This test is specified in 49 CFR 173.176 and covers both safety matches and strike-anywhere matches. The required test is specified as follows:

> "Strike-anywhere matches (or safety matches), when offered for transportation, must be of a type which will not ignite spontaneously or undergo marked decomposition when one complete inside package is subjected for eight consecutive hours to a temperature of 200°F (93.3C)."

There does not appear to be any reason why the criteria used for matches should not be equally applicable to determining the pyrophoricity and/or flammability of uranium and other potentially pyrophoric metals and for mixtures of these metals with sand and other inerting media. However, tests should be conducted to determine whether 200°F (93.3C) is a proper temperature in the case of depleted uranium and other metals.

Continuing to classify all uranium metal as a pyrophoric regardless of form and size can have significant economic consequences. It will be very expensive to require inerting and the use of Type A containers as compared to L.S.A. shipments in strong tight industrial containers.

b. Requirements for Disposal

The regulations and most licenses for the disposal of low-level radioactive materials preclude the disposal of pyrophoric materials. 10 CFR 61.56(a)(6) states:

> "(6) Waste must not be pyrophoric. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable."

10 CFR 61.2 defines pyrophoric materials as follows:

> "Pyrophoric Liquid" means any liquid that ignites spontaneously in dry or moist air at or below 130°F (54.5°C). A pyrophoric solid is any solid material, other than one classed as an explosive, which under normal conditions is liable to cause fires through friction, retain heat from manufacturing or processing, or which can be ignited readily and when ignited burns as vigorously and persistently as to create a serious transportation, handling or disposal hazard. Included are spontaneously combustible and water reactive materials."

Based on these requirements and definitions, depleted uranium, when packaged for disposal, should also be shown to be non-reactive if submerged in water. This would provide the necessary assurance that a hazard would not result if the disposal site should become inundated with water. The oxidation potential in water can be readily determined by monitoring for the release of hydrogen.

The licenses for the three commercial disposal sites preclude the disposal of pyrophoric materials. The

licenses predate 10 CFR 61 and are generally based on the DOT requirements for transportation.

4. DISPOSAL AT COMMERCIAL DISPOSAL FACILITIES

The depleted uranium waste generated by the manufacturers of depleted uranium munitions is being routinely disposed of at the three commercial disposal sites. Materials suitably packaged for transportation are generally accepted for disposal without question. The waste generated at Eglin AFB consisting primarily of penetrator fragments and small quantities of sand was shipped to commercial disposal sites until 1983. However, none of the contaminated residual sand from the target butt changes has been disposed of at commercial sites.

a. Requirements for Disposal at Barnwell, SC

The State of South Carolina is an agreement state, and as such, regulates the disposal activities at the Barnwell Waste Management Facility. The Department of Health and Environmental Control is the state agency responsible for the site. The Barnwell Waste Management Facility Site Disposal Criteria (Reference 8) contain the following provisions relative to the disposal of depleted uranium.

"10.8 Pyrophoric Materials

10.8.1 Pyrophoric material contained in wastes shall be treated, prepared and packaged to be non-flammable and rendered non-pyrophoric prior to shipping.

10.8.2 The process for rendering the material non-pyrophoric must be submitted and approved by the Manager, Regulatory Affairs (Barnwell) prior to shipping.

10.8.3 No material that might react violently with water or moisture shall be accepted for disposal at the Barnwell Site.

10.8.4 Questions concerning these materials should be directed in writing to the Manager, Regulatory Affairs (Barnwell)."

In addition, the State of South Carolina has recently imposed special requirements on the disposal of incinerator ash or powders, such as baghouse dust. These requirements affect the manufacturers of depleted uranium munitions who incinerate uranium turnings, chips and scraps. It may also affect future operations at the Heavy Metal Test Facility at Eglin AFB. Section 45 of the general conditions of South Carolina Department of Health and Environmental Control Radioactive Material License 097, covers the disposal of dispersible waste as follows:

> "45. The Licensee shall not receive radioactive waste in the forms of incinerator ash or powder which may be dispersible unless solidified with a media specified in Condition 33 of this license, or packaged to prevent dispersion as specifically approved by the Department. In lieu of solidification, these waste forms may be received in high integrity containers approved by South Carolina

Department of Health and Environmental Control provided the waste is stablized with a binding matrix."

To date, no criteria have been issued as to what constititues packaged to prevent dispersion or stabilized with a binding matrix. In discussions with the South Carolina Department of Health and Environmental Control, they have indicated that material must not be dispersible by wind or water in the event that a container should split open.

b. Requirements for Disposal at Beatty, NV and Richland, WA

The license for the Beatty, Nevada (Reference 9) sites does not contain any special provisions relative to the disposal of depleted uranium or pyrophoric radioactive waste. The general provisions for packaging of waste are as follows:

> "20. All radioactive materials accepted for disposal shall be packaged in accordance with current U.S. Department of Transportation (DOT) regulations for the transportation of radioactive material, and shall be disposed of in these DOT containers unless otherwise specified by this license. Improperly packaged radioactive materials shall not be disposed of by the licensee unless specific authorization for disposal is granted by the Radiological Health Section, Nevada Division of Health."

The license for the Richland, Washington facility (Reference 10) contains similar general provisions for the

packaging of waste and the following specific requirements for pyrophoric materials.

> "27. No pyrophoric or chemically explosive radioactive material that might react violently with water, moisture or agitation shall be accepted for disposal at the site without prior approval by the Department.
>
> Waste must not contain, or be capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste. This does not apply to radioactive gaseous waste packaged in accordance with Condition 28 of this license."

c. Cost of Disposal at Commercial Disposal Facilities

Estimates were made of the cost to dispose of the current inventory of 3,500 drums of waste at commercial disposal facilities. Eglin AFB does not have a space allocation at the Barnwell Waste Management Facility. If the waste is to be disposed of in the near future, it may be necessary to ship the waste to one of the western disposal sites. Table 6 is a summary of the estimated cost of transporting and disposing of the current waste inventory at each of the three commercial disposal sites.

These cost estimates cover only the cost of transportation and disposal. They do not include the cost of processing and repackaging of the material, nor do they include the cost of containers. The estimated costs for disposal at Barnwell, SC are based on the 1984 price schedules which were in effect when this work was performed.

TABLE 6. DISPOSAL AT COMMERCIAL DISPOSAL FACILITIES

Transportation and Disposal Cost
(3,500-Drum Inventory)

	Richland, WA	Beatty, NV	Barnwell, SC
Mileage[1]	2589	2020	582
Transporation Cost2	$ 299,600	$ 240,450	$ 71,600
Burial Cost[3]	$ 571,200	$ 517,080	$ 669,043
Total Cost	$ 870,800	$ 757,530	$ 740,643
Cost $/Cf	$ 33.17	$ 28.86	$ 28.21

[1] Mileage from Eglin AFB to the disposal facility.

[2] Based on one-way mileage commodity rates effective October 15, 1984, for low-level radioactive waste.

[3] Based on burial cost price schedules in effect on January 1, 1985, and does not include cost of burying pallets.

Current estimates of the costs including repackaging are contained in Section III of this report.

d. Low-Level Radioactive Waste Policy Act of 1980

With the enactment of the Low-Level Radioactive Waste Policy Act in December 1980, responsibilities for the disposal of low-level radioactive waste were defined as follows:

- Each state was made responsible for the disposal of low-level radioactive waste generated within its borders.

- States were required to make provisions for handling their waste by January 1, 1986.

- States were encouraged to enter into Compacts for the development of regional low-level waste disposal facilities.

- Regional Compacts must be approved by the U.S. Congress.

- Congress may withdraw consent of Compacts after 5 years.

- After January 1, 1986, the regional Compacts may restrict the use of the facility for waste generated outside the Compact.

The states of Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia have agreed to enter into the Southeast Interstate Low-Level Radioactive Waste Management Compact. Bills have been introduced in the House of Representatives and the U.S. Senate to grant the consent of Congress to this Compact (References 11 and 12). Under this Compact, the state of South Carolina would continue to be the host state and accept waste until 1992 at the Barnwell, South Carolina facility. The Southeast Compact has initiated studies to select a site which is to be in operation to replace the Barnwell disposal facility in 1992.

Since the Eglin AFB is located in the State of Florida and Florida is a party state in the Southeast Compact, burial space should be available to the Air Force at the Barnwell Facility beginning in 1986 and at the disposal facility that will replace Barnwell in 1992. However, there

are a number of complicating factors. The Southeast Interstate Low-Level Waste Management Compact defines the low-level radioactive waste for which they are responsible as follows:

> "The party states recognize and declare that each state is responsible for providing for the availability of capacity either within or outside the state for disposal of low-level radioactive waste generated within its borders, except for waste generated as a result of defense activities of the federal government or federal research and development activities. They also recognize that the management of low-level radioactive waste is handled most efficiently on a regional basis."

In telephone discussions with the Executive Director of the Southeast Compact, it was noted that the phrase, "except for waste generated as a result of defense activities of the federal government" might be applied to the waste being generated at Eglin AFB in the testing of depleted uranium armor penetrators. This could preclude the acceptance of the waste being generated at Eglin AFB, at Barnwell after the Southeast Compact is approved, and at future disposal sites in the Southeast Compact. This being the case, the Department of Energy would be obligated to accept the waste since commercial disposal facilities would not be available due to no fault of the Air Force.

The defense related exclusion would probably not apply to the manufacturers of depleted uranium penetrators. By precedent, the manufacture of munitions is considered to be an industrial activity.

Although significant progress has been made to establish Compacts and to initiate plans for regional disposal facilities, no new low-level radioactive waste disposal facilities will be available by January 1, 1986. If Congress were to approve the Compacts that have been proposed without amending the Low-Level Radioactive Waste Policy Act of 1980, only three compacts would have disposal facilities, and these compacts would have the right to exclude waste from generators outside of the compacts. The Low-Level Radioactive Waste Policy Act Amendments of 1985 have been reported by subcommittees. In summary, these amendments would:

- Define low-level radioactive waste to exclude only DOE and nuclear related defense waste.
- Extend transition period and guaranteed access to current disposal sites from January 1, 1986 until December 31, 1992.
- Require States without disposal sites to meet milestones for new sites.
- Establish ceilings on the amount of waste to be accepted during the transition period.
- Allocate disposal space to nuclear generating facilities based on type, age and location.
- Provide disposal capacity for non-utility waste from states without disposal sites.
- Impose surcharges on waste from generators in states without a disposal facility.

5. ON-SITE DISPOSAL

a. Title 10 Code of Federal Regulation Part 20

Prior to 1981, Section 20.304 of the Standards for Protection Against Radiation, 10 CFR 20, provided general authority for the disposal of radioactive materials by burial in soil. Under this section, licensees were permitted to disposal of licensed material by burial in soil provided:

- The total quantity of radioactive material buried at one location and at one time does not exceed 1000 times the amount specified in Appendix C (Natural Uranium; 100 μCi).

- Burial is at a minimum depth of 4 feet.

- Successive burials are separated by distances of at least 6 feet.

- No more than 12 burials are made per year.

This general authority would allow the annual burial of 880 pounds of material contaminated with natural uranium and having a concentration of 3000 pCi per gram.

Effective January 28, 1981, the regulations were amended to delete Section 20.304. Under the amended regulations, licensees must apply for and obtain specific approval for the burial of radioactive material under the provisions of 10 CFR 20.302. With the deletion of Section 20.304, applications for the burial of radioactive waste are required to demonstrate that local land burial is preferable to other disposal alternatives. On October 23, 1981, a Branch Technical Position was issued (References 13 and 14). This

Branch Technical Position specifically addressed sites formerly used for processing thorium and uranium which have been contaminated with residual radioactive materials. The Branch Technical Position states:

> "In many cases, the total amount of contaminated soil is large, but the activity concentrations of radioactive materials are believed sufficiently low to justify their disposal on privately owned lands or storage onsite rather than their transport to a licensed radioactive materials disposal (commercial) site."
>
> "In many instances packaging and transporting these wastes to a licensed disposal site would be too costly and not justified from the standpoints of risk to the public health or cost-benefit."
>
> "... because of the total volume of these wastes, limited commercial waste disposal capacity, and restrictions placed on receipt of long-lived wastes at commercial sites, it is not presently feasible to dispose of these wastes at commercial low-level waste disposal sites."

This Branch Technical Position is intended to apply to licensed and unlicensed sites contaminated during past operations. However, the rationale for on-site burial is equally applicable to the sand contaminated with low concentrations of depleted uranium currently being generated at Eglin AFB. In discussions with representatives of the Nuclear Regulatory Commission, it was confirmed that the same criteria could be applied to on-going operations subject to hydrological, geological, environmental and other factors.

The U.S. Nuclear Regulatory Commission has issued a notice (Reference 15) which encourages licensees to submit applications under 10 CFR 20.302 for the disposal of large volumes of material contaminated at very low levels.

The Branch Technical Position established criteria for the on-site disposal of waste based on the concentrations of the waste. The disposal options for depleted uranium are summarized in Table 7. Table 8 shows the basis for each of the disposal options and the restrictions that must be applied. Option 4 shows the highest concentrations allowed for on-site disposal. Materials having depleted uranium concentrations greater than 1000 pCi per gram for soluble material and 3000 pCi per gram for insoluble can only be stored on-site for later disposal at appropriate disposal facilities.

At the present time, practically all of the waste being generated at Eglin AFB exceeds the limits for on-site disposal even under Option 4. Section VI discusses methods by which the contamination of the sand can be reduced to allow on-site disposal of a major portion of the waste under 10 CFR 20.302 and the Branch Technical Position.

b. Title 10 Code of Federal Regulations Part 61

An on-site disposal facility to handle all of the waste presently being generated at Eglin AFB would have to be licensed under 10 CFR 61. Because Eglin AFB is located in a humid climate and a coastal environment, various types of engineered disposal concepts were considered in addition to improved shallow land burial. Conceptual designs and cost estimates were prepared for the following disposal concepts:

Shallow land burial
Above-ground vault

TABLE 7. SUMMARY OF NRC POLICY ON DISPOSAL OF DEPLETED URANIUM

Material	Disposal Options[a] 1	2	3	4
Depleted Uranium				
o Soluble[b]	35	100	N/A	1000
o Insoluble[c]	35	100	N/A	3000

(a) - Units are pCi/g

(b) - Limiting organ is lung

(c) - Limiting organ is bone

N/A - Not applicable

TABLE 8. BASIC AND RESTRICTIONS OF DISPOSAL OPTIONS

Option	Basis	Comment
1	EPA Cleanup Standards	No restrictions
2	Limits individual doses to 170 mRem/yr	At least 4 foot soil cover. Acceptance of site based on topograpical, geological, hydrological and meteorological conditions.
3	--- Applies only to natural uranium ---	
4	Limits individual doses to 500 mRem/yr	As in Option 2, plus deed restriction (covenant) on use of land for residential or industrial building, agriculture, or excavation of site.
5	Storage for later disposal at appropriate facility	Radiation doses not to exceed 10 CFR Part 20 and are as low as is reasonably achievable (ALARA).

Above-ground vault with cover
Below-ground vault
Mounded concrete bunker
Concrete canister
Concrete canister with drums
Concrete canister with bulk storage
Pipe caisson
Augered caisson

Appendix A contains sketches, descriptions and cost estimates for each of these disposal concepts.

Figure 4 shows the comparative costs of on-site disposal at Eglin AFB for each of these concepts. Table 9 shows the breakdown of the development, operating, closure and institutional control costs. Table 10 compares the desirable disposal unit characteristics associated with each of these disposal concepts.

It was concluded that an on-site disposal facility licensed under 10 CFR 61 was not a viable alternative and did not warrant further consideration. The disposal costs associated with the least cost on-site disposal alternative (i.e., above ground at $40.07 per cubic foot) exceed the cost of off-site disposal at commercial facilities (See Table 9, Costs $28.21 to $33.70 per cubic foot) and disposal at Department of Energy facilities (See Table 9, Costs $9.53 to $11.57 per cubic foot). In addition, the above-ground vault does not provide all of the features that one would want in a disposal facility in the Eglin AFB environment. The information on these on-site disposal concepts is being reported primarily for comparison with the alternatives selected for detailed evaluation.

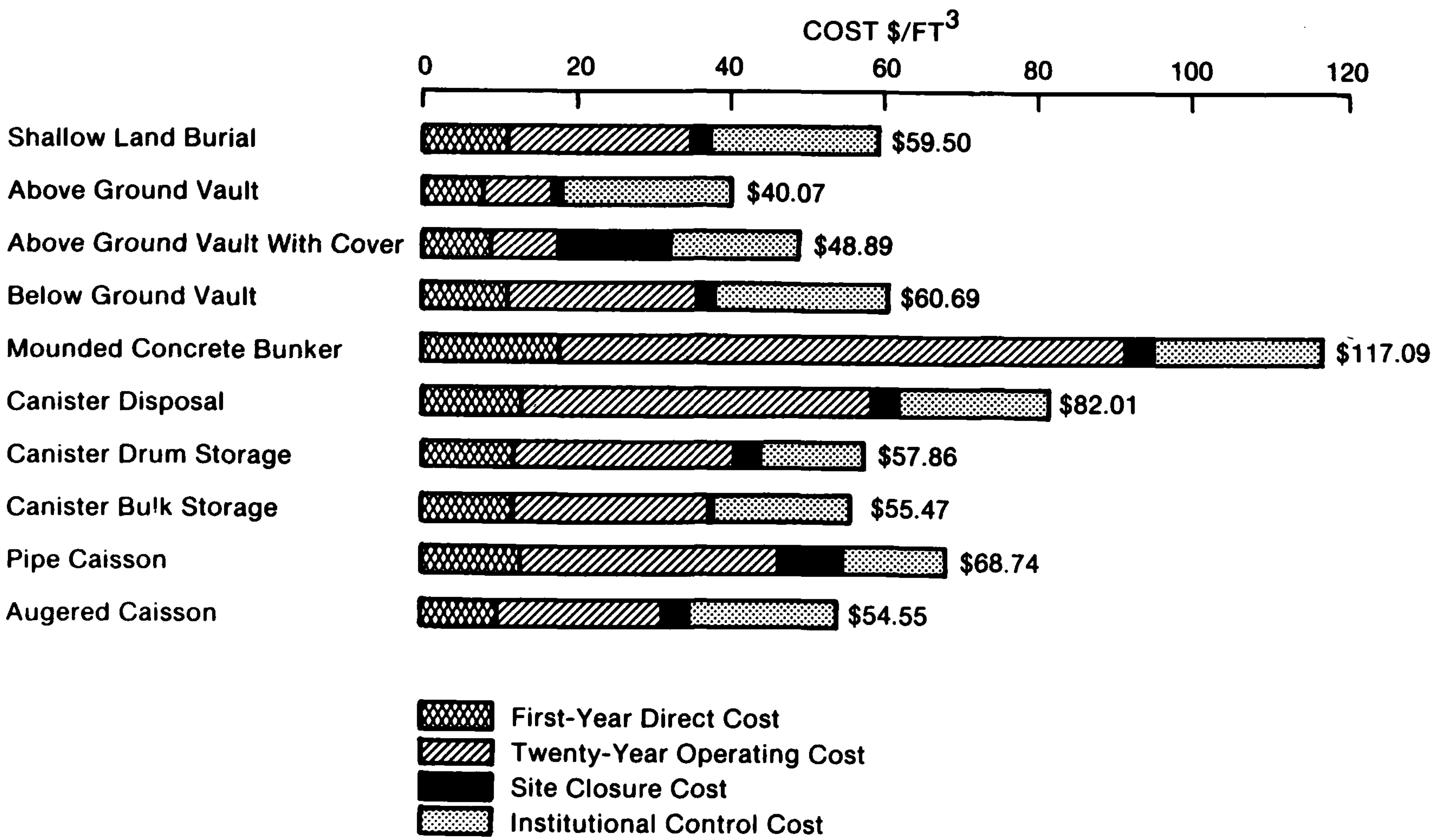

Figure 4. Comparative Costs of Disposal Options

TABLE 9. COST SUMMARY OF DISPOSAL OPTIONS
($ x $1,000)

	Shallow Land Burial	Above Ground Vault	Above Ground Vault/ Cover	Below Ground Vault	Mounded Concrete Bunker	Concrete Canister	Concrete Canister Alter. 1	Concrete Canister Alter. 2	Pipe Caisson	Augered Caisson
First-Year Direct Cost	2,035	1,549	1,560	2,067	3,450	2,650	2,197	2,197	2,293	1,943
Twenty-Year Operating Cost	5,204	2,058	2,064	5,399	13,858	8,835	5,325	4,893	6,682	4,591
Site Closure Cost	55	41	2,273	55	65	56	48	48	55	48
Institutional Control Cost	4,086	4,016	3,454	4,086	5,020	4,144	3,495	3,470	4,117	3,851
Total Cost	11,380	7,664	9,351	11,607	22,393	15,685	11,065	10,608	13,147	10,433
Cost/Ft^3	59.50	40.07	48.89	60.69	117.09	82.01	57.86	55.47	68.74	54.55

TABLE 10. DISPOSAL FACILITY CONCEPTS COMPARISON

Disposal Unit Characteristics	Shallow Land Burial	Above Ground Vault	Above Ground Vault With Cover	Below Ground Vault	Mounded Bunker	Concrete Canister	Pipe Caisson	Augered Caisson
Control Surface Water Intrusion	•	•	•	•	•	•	•	•
Barrier to Radionuclide Migration	•	•	•	•	•	•	•	•
Control Trench Cap Subsidence		N/A	•	•		•	•	N/A
Control Ground Water Intrusion	•	•	•	•	•	•	•	•
Plant/Animal Intrusion Barrier	•	•	•	•	•	•	•	•
Intruder Protection - Structural		•	•	•		•	•	•
Secondary Control of Surface Water Intrusion			•	•		•	•	•
Secondary Control of Ground Water Intrusion			•	•	•	•	•	•
Not Vulnerable to External Events	•			•	•	•	•	
Long-Term Structural Integrity	•		•	•	•	•	•	
Additional Intrusion Barriers			•	•		•	•	
Secondary Barrier to Radionuclide Migration			•			•	•	
Isolates Waste from Erosion or Mass Earth Movement		•	•	•		•	•	•
Does Not Require Long-Term Structural Maintenance	•		•	•	•	•	•	
Not Susceptible to Seismic Events	•					•	•	

c. Hydrologic, Geologic, and Environmental Investigations

As part of the identification of alternatives, investigations were made of Eglin AFB to identify conditions that would have a major influence on the siting and licensing of a disposal facility at this location. This work was performed to support a disposal facility for materials having low levels of contamination under 10 CFR 20.302 or a facility capable of handling all of the waste and licensed under 10 CFR 61.

Visits were made to Eglin AFB and the Northwest Florida Water Manager District, the U.S Geological Survey Office, and the Department of Environmental Regulation in Tallahassee, Florida. All environmental reports that had been prepared relative to the Eglin AFB site and the test site were reviewed.

Information was compiled relative to the hydrogeologic conditions at the test site. This information was presented at the First Program Review. Based on this information, it was concluded that a disposal site for materials having low levels of contamination was possible.

6. RECYCLING OF DEPLETED URANIUM

After firing into the sand butt, the majority of the penetrator fragments are quite large. At the end of each firing cycle, the larger fragments are removed by sieving with a mechanical sieve having a one-half inch mesh. The fragments retained by the sieve plus balls of wet sand are placed into 16 to 18-gallon drums. Using the available data, it would appear that the weight of the recovered fragments can be as much as 60 percent of the total weight of the

penetrators fired into the target during the firing cycle. A normal firing cycle consists of approximately 25,000 penetrators having a total weight of 16,500 pounds. With a recovery of 60.5 percent, 10,000 pounds of depleted uranium can potentially be recovered from each firing cycle. The drums containing the recovered penetrators and sand generally contain 55 to 60 percent penetrators on a weight basis.

In 1982, 28 18-gallon drums of recovered penetrators were shipped to Nuclear Metals, Inc. in Concord, MA to determine the feasibility of recovering the depleted uranium (Reference 16). These drums were filled with material sieved from the target after a firing cycle of 20,268 depleted uranium penetrators and 13 test penetrators. The weight of the uranium penetrators fired into the target during the firing cycle was about 13,400 pounds. Prior to melting, the fragments were first etched with a sodium hydroxide solution, and the aluminum wind screen fragments were manually removed. The fragments were then pickled in nitric acid, followed by a water rinse and drying. The fragments were melted utilizing a VIR furnace. Four casting heats were made with the recovered depleted uranium fragments, and 31 billets were casted. The charge weight was 6,136 pounds, and the weight of the billets was 5,923 pounds for an overall casting yield of 96.5 percent. The recycled material met the chemical requirements for the GAU-8 penetrators.

The overall recovery based on penetrators actually fired was 44 percent.

Although recycling of penetrators is desirable to conserve a valuable resource, it has minimal effect on waste disposal. The reduction in the volume of waste requiring disposal is at most 1 to 2 percent.

During the evaluation of alternatives phase, special tests were conducted to determine whether sieves with smaller openings could remove additional uranium and reduce the concentration of the sand requiring disposal. The objective was to reduce the concentration to below 3000 picocuries per gram. This would allow the sand passing through the sieve to be disposed of on-site under 10 CFR 20.302. Unfortunately, the sieves with smaller openings did not reduce the contamination levels to anywhere near this value. In addition, removal of additional fine grained material would result in more of the recovered uranium being oxidized which would reduce the recycling yields.

7. CONCLUSIONS OF THE TASK 1 EFFORT

The work on the identification of alternatives led to a number of conclusions. These are summarized on Table 11.

8. SELECTION OF ALTERNATIVES FOR INVESTIGATION

The results of the Task 1 effort were presented at a Project Review meeting held on January 16-17, 1985. Following this review, the Air Force selected the alternatives to be investigated in Task 2 (Reference 17). Table 12 contains a listing of these alternatives.

TABLE 11. CONCLUSIONS OF THE TASK 1 EFFORT

On-Site Disposal

- Eglin AFB Not Suitable for 10CFR61 Facility,
- On-Site Disposal More Expensive Than Off-Site Disposal,
- On-Site Disposal of Contaminated Material Potentially Attractive.

Packaging for Transport

- Pyrophoric Materials Require Inerting in Type A Packages,
- Oxidizing Potential Phyrophoric Material Allows LSA Shipments.

Disposal at DOE Facilities

- Not Permitted If Commercial Facilities Available,
- Contingency Plans Needed By Eglin AFB and Manufacturers,
- Waste May Be Excluded From Southeast Compact as Defense Related.

Disposal at Commercial Facilities

- Waste Must Be Repackaged For Shipment/Disposal,
- No Space Allocation At Barnwell For Eglin AFB,
- Low Burial Prices At Beatty Offset Transport Costs,
- Dispose of Present Inventory Before January 1, 1986.

Recycling of Depleted Uranium Waste

- Recycling of D.U. Fragments Previously Demonstrated
- Potential Recovery of 10,000 pounds DU per 25,000 Rounds,
- Additional Recovery Not Practical or Desirable,
- Inerted Containers Required For Transport,
- Present Inventory Requires Repackaging.

TABLE 12. ALTERNATIVES APPROVED FOR INVESTIGATION IN TASK 2

- Disposal of current inventory of sand and depleted uranium at the commercial disposal facility at Beatty, Nevada.

- Initiate a program for the recycle of penetrator fragments in depleted uranium products.

- Develop procedures and equipment for the inerting and stabilization of depleted uranium fragments in the event that the industry is not interested in recycle.

- Develop plans and procedures for the packaging and disposal of future waste as it is generated.

- Develop contingency plans for the shipment of depleted uranium waste to DOE disposal facilities in the event that commercial burial sites are not available.

- Develop concepts for the on-site disposal of all depleted uranium waste in accordance with 10 CFR 61 and evaluate and rank the concepts with other disposal alternatives.

SECTION III

DISPOSAL OF PRESENT INVENTORY

1. CONTAMINATED SAND

Over 90 percent of the current waste inventory at Eglin AFB is the 3,500 drums of contaminated sand. This is the sand from the three changes of the target butt after the sand became pulverized and no longer effective as a target material. In all but one case, the penetrator fragments were sieved from the sand prior to placement in the drums. As previously shown in Figure 2, the concentrations of depleted uranium range from 1 to 5 percent on a weight basis, with some of the drums having concentrations as high as 20 weight percent. The concentration of depleted uranium in the contaminated sand is higher than the limits for on-site disposal under 10 CFR 20.302 (i.e., 3000 picrocuries per gram insoluble and 1000 picocuries per gram soluble). In addition, tests have shown that it is not feasible to reduce the concentrations of uranium by the use of sieves having a closer spaced mesh. For these reasons, the contaminated sand must be disposed at a licensed commercial burial site or at a Department of Energy disposal site if commercial burial space is not available. Because of the uncertainties relative to the availability of burial space after January 1, 1986, the disposal of the contaminated sand should take place as soon as possible.

a. Packaging for Transportation and Disposal

The contaminated sand in most of the drums is damp and in some cases wet. Water is sprayed on the target butt and during the sieving operations to reduce the possibility of airborne contamination. To meet shipping and burial

requirements, the depleted uranium in contaminated sand must be inerted with dry sand or blended into a concrete matrix. Three alternative methods for inerting the contaminated sand were considered. These were:

- Addition of water and cement to form a free standing cement matrix.
- Drying using a combination of wrap around drum heaters and immersion heaters.
- Drying in a rotary dryer of the type used in sand, gravel and mineral operations (See Figure 5).

Table 13 is a summary of the cost for processing, repackaging, transportation and disposal of the present inventory of contaminated sand using each of the three alternative packaging methods. The assumptions used in making these estimates are contained in Appendix B.

TABLE 13. ALTERNATIVE METHODS FOR DISPOSAL OF PRESENT INVENTORY*

	Solidification	Drying Drum Heater	Drying Rotary Heater
Repackaging	$ 337,000	$ 286,000	$ 305,000
Compact Old Drums	148,000	148,000	148,000
Transportation	342,000	260,000	260,000
Burial	566,000	566,000	566,000
Total	$1,393,000	$1,260,000	$1,279,000

* 3500 drums of contaminated sand.

Figure 5. Rotary Dryer for Sand and Gravel

As shown in Table 13, drying is less expensive than solidification. Of the two methods of drying considered, the use of a rotary dryer is recommended for the following reasons:

The total cost is only 1.5 percent higher.
Uses a portable propane tank.
Does not require special electrical service.
Equipment is more rugged and reliable.
Better quality control of the product.
Better suited for future operation.
Lower operating costs.
Oxidizes potentially pyrophoric materials.

In the evaluation of alternative processing methods, it was assumed that all of the contaminated sand would be repackaged in new 17H steel drums. This assumption was based on having to classify the depleted uranium as pyrophoric in accordance with 49 CFR 172.101 and shipping the material in accordance with 49 CFR 173.418 and the other applicable regulations. As discussed in Section II.3.a., it was considered that the depleted uranium in the contaminated sand can be rendered non-pyrophoric by drying in the rotary dryer. This being the case, the contaminated material could then be shipped as Low Specific Activity Material (LSA) using strong tight industrial containers. Many of the drums now being used to store the contaminated sand can be classified as strong tight industrial containers and used to transport the contaminated sand after drying. This reduces the number of new drums that must be procured. It also reduces the cost of disposal of the existing drums. Table 14 shows the cost of replacing and disposal of the 3,500 drums. Table 15 shows the revised cost of reprocessing, packaging, transportation and disposal, if 50 percent of the existing drums are reused. As indicated this can potentially save $132,000 which would

TABLE 14. COST TO DISPOSE OF PRESENT DRUMS
(3500 Drums)

Compaction		$148,000
Labor	$ 6,000	
Compactor Charge	129,500	
Overpacks	12,500	
Transportation		25,000
Burial		54,000
Total		227,000
Replacement Drums		88,000
Total Cost Including Replacement Drums		$315,000

TABLE 15. COST OF DISPOSAL USING ROTARY DRYER
(WITH 50 PERCENT REUSE OF EXISTING DRUMS)

Repackaging		$260,500
Material & Equipment	$122,500	
Labor	138,000	
Disposal of Drums		114,000
Labor	3,000	
Compactor Charge	65,000	
Overpacks	6,500	
Transportation	12,500	
Burial	27,000	
Disposal of Contaminated Sand		
Transportation		260,000
Burial		512,500
Total		$1,147,000
Potential Savings		$ 132,000

more than offset the cost of procuring and installing the rotary dryer.

In order to use this approach, it will be necessary to obtain the concurrence of the Department of Transportation that the material can be made non-pyrophoric and therefore suitable for transport as LSA. This will undoubtedly require testing. In addition, it will be necessary to obtain the concurrence of the disposal facility that the material has been rendered non-pyrophoric and not reactive if immersed in water.

The cost estimates shown in Tables 13, 14, and 15 all assume that non-usable drums would be processed using a high force mobile compactor. This will reduce the height of the empty drums to about 2.5 inches and will allow 14 compressed drums to be placed in an 80-gallon steel overpack (diameter: 25 inches, height 38 inches). The cost of mobilization and usage of the compactor has been estimated at $32.27 per drum. This cost is much less than the cost of burying the empty drums or decontaminating the drums to allow on-site disposal.

Figure 6 shows the operations involved in the drying, processing and packaging of the contaminated sand.

b. Rail Transportation

The estimates contained in Tables 13, 14, and 15 assume that the waste is transported by truck to the commercial disposal site at Beatty, Nevada. Rail shipments were also considered as means of reducing transportation costs. Routing via the Seaboard System Railroad and the Union Pacific/Missouri Pacific Railroad from Eglin AFB to Beatty, Nevada was considered based on the following assumptions:

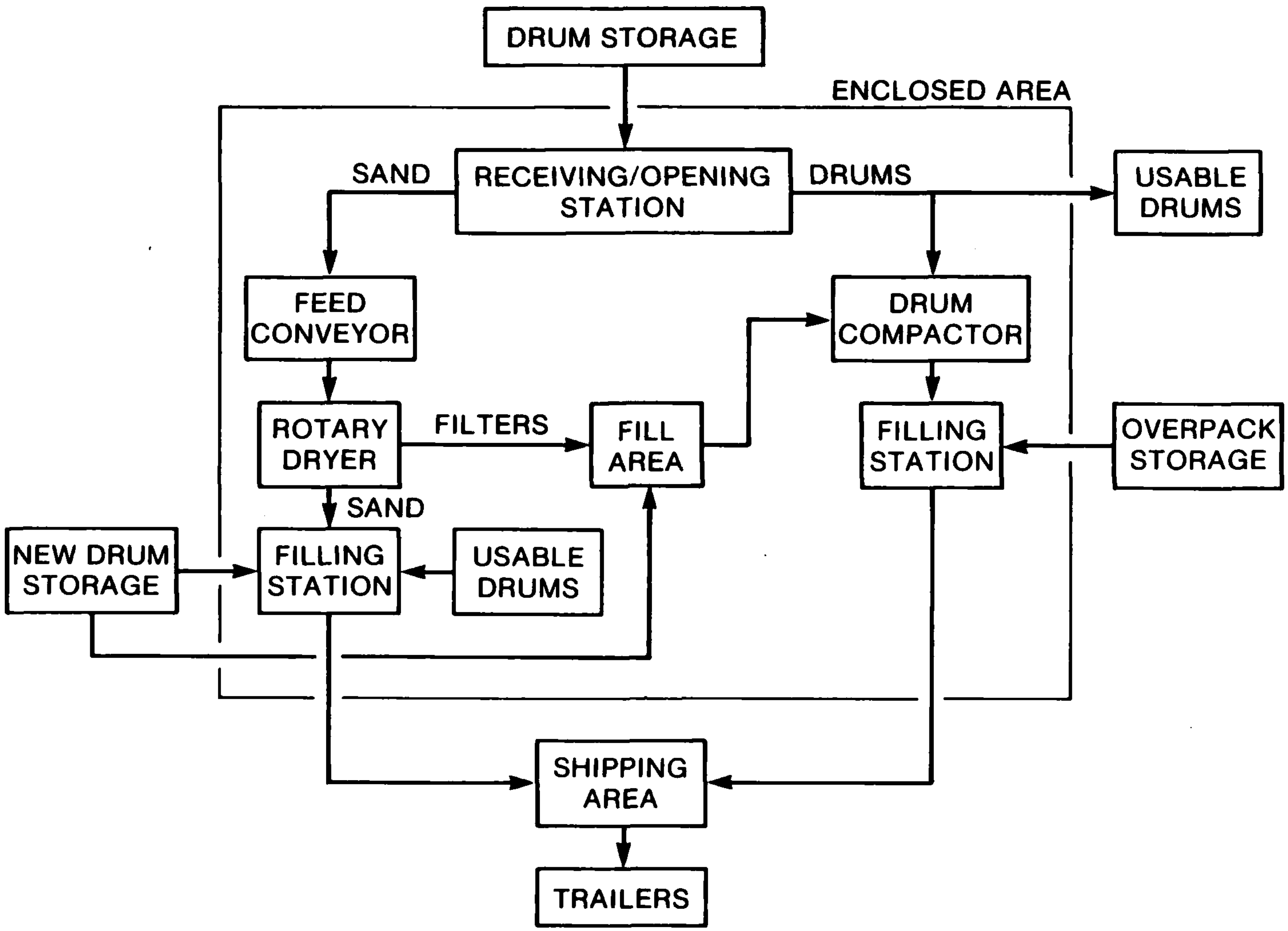

Figure 6. Drying, Processing and Packaging of Contaminated Sand

- Piggyback shipment with unit train.

- Railroad supplied trailers.

- Includes pickup at Eglin AFB and transport to Mobile, Alabama.

- Includes transport from Las Vegas to Beatty, Nevada.

- Net Payload: 45,000 pounds

- Price: $3,337/trailer.

Table 16 is a comparison of the estimated cost of truck and rail transport. As noted, rail shipment can potentially save $123,848. However, truck transportation is highly competitive and trucking firms may lower prices to be competitive with rail transport.

TABLE 16. COMPARISON OF TRUCK AND RAIL TRANSPORT

	Truck Shipment	Rail Shipment*
Number of drums	3,500**	3,500**
Weight per drum	750	750
Allowable Weight per trailer	40,000	45,000
Number of drums per trailer	53	60
Number of trailers	66	58
Price per trailer	$ 4,809	$ 3,337
Total Price	$317,394	$193,546
Potential Savings		$123,848

*Based on piggyback shipments

**Does not include used drum disposal

2. PENETRATOR FRAGMENTS

The present inventory of waste material at Eglin AFB includes 58 18-gallon steel drums containing penetrator fragments that have been removed by sieving and sand. The sand in these packages is damp or wet for the reasons previously noted, and the material must be inerted for shipment. Based on the weight of the drums, the uranium content could be as high as 60 percent. The weight of the fragments contained in the 58 drums could be as much as 16,000 pounds. For this reason, it is recommended that this material be made available to manufacturers of depleted uranium products for recycling rather than disposing of this material as waste.

Before the penetrator fragments can be shipped, it will be necessary to dry the sand and repackage the penetrator/sand mixture in new inerted containers. The methods for handling penetrator fragments are discussed in detail in Section IV of this report.

3. HIGH EFFICIENCY PARTICULATE FILTERS

The present waste inventory includes 80 55-gallon drums containing HEPA filters. The HEPA filters are used to control the ventilation of the building which houses the target butt, and the filters collect the airborne particulates. The depleted uranïum is virtually all oxidized, and the filters do not need to be considered as pyrophoric materials. This will allow the material to be shipped as LSA This will permit most of the present drums to be used.

4. ARMOR PLATE AND CONCRETE BLOCKS

There are a number of armor plates and concrete blocks at the Eglin AFB test site that were used in tests of depleted

uranium penetrators. These plates and blocks have some localized depleted uranium contamination. The cost of transporting and disposal of these plates and blocks would be prohibitively expensive because of their size and weight. Since the contamination is localized, it is recommended that the plates and blocks be decontaminated to the levels required for free release of radioactive materials. The free release limit is normally defined as 100 disintegrations per minute per 100 cm^2. If possible, the plates and blocks should be decontaminated to the non-detectable limit which is normally defined as less than 50 dpm per 100 cm^2.

SECTION IV

RECYCLING AND DISPOSAL OF PENETRATOR FRAGMENTS

1. SEPARATION AND RECLAMATION OF PENETRATOR FRAGMENTS

The practice of separating the penetrator fragments from the target butt sand was initiated primarily to permit the sand to be reused. After a large number of penetrators have been fired into the target butt, the penetrators being fired impact the penetrators in the butt and cause ignition and oxidation of the uranium. The presence of a large number of penetrators in the butt also causes ricocheting of the penetrators and could create a safety hazard. After approximately 25,000 penetrators have been fired into the target butt, the core is removed, and the penetrators are removed from the sand by using a mechanical sieve. Experience indicates that the weight of the uranium fragments removed by sieving will be about 60 percent of the weight of the penetrators fired into the target butt. The penetrator fragments and the retained sand are placed in 16- to 18-gallon steel drums. The sand passing through the sieve is returned to the sand butt, and additional sand is added as needed. After about four firing cycles of 25,000 rounds each, the sand becomes pulverized, and the entire sand butt is replaced.

In the past, the drums containing the penetrator fragments and sand were shipped to commercial disposal sites for burial as waste. In October 1981, 28 drums of depleted uranium fragments and sand were shipped to Nuclear Metals, Inc. in Concord, MA to determine the feasibility of recovering and recycling depleted uranium. It was found that the depleted uranium fragments could be reclaimed and were suitable for recycle as GAU-8 munitions. The results of this

program were previously summarized in Section II of this report and are fully reported in Reference 11.

Approximately 10,000 pounds of depleted uranium fragments can be recovered from each firing cycle of 25,000 penetrators.

A series of tests were conducted during this project to determine whether the additional uranium could be recovered by using finer mesh sieves. Four samples containing sand and depleted uranium were taken from drums stored at the test site. Each sample was analyzed for depleted uranium content and then sieved using a No. 5 U.S. Sieve (opening 0.157 inches). The amount of material remaining in the sieve was analyzed to determine the uranium concentrations and the percentage of depleted uranium removed. The results were as follows:

Drum Number	Original Concentration (%)	Uranium Removed (mg/g)	Final Concentration (%)	Fraction Removed (%)
42	12.92	71.3	5.79	55.2
600	4.55	18.36	2.72	40.3
916	0.88	0.14	0.74	1.6
1052	0.31	*	0.30	n.a.

*Below limits of detection.

As shown in Figure 2, the majority of the contaminated sand has uranium concentrations in the range of 1 to 10 percent. The two samples in this range (i.e., 42 and 600), had removals of 40 to 55 percent with the finer mesh sieve. However, the uranium concentrations in the sand still ranged from 2.7 to 5.8 percent. These concentrations still exceed

the maximum concentration that can be considered for on-site disposal (~ 1 percent). The amount of depleted uranium that could be removed from a sample (No. 916) with a concentration slightly below the allowable limit (i.e., 1 percent) was minimal (i.e., <2 percent). Based on these results it was concluded that sieving with finer mesh sieves could not reduce the concentrations to allow for on-site disposal. In addition, personnel involved in the recycle program have also indicated that the recovery of smaller fragments would not significantly increase yield due to the difficulty in separating the smaller particles and the increased amount of oxidized material.

2. PACKAGING OF PENETRATOR FRAGMENTS

The contents of the drums are generally damp and in some cases wet from the water used to control airborne contamination. At a minimum, the sand must be dried. Because of the amount of depleted uranium in each of the drums, it is recommended that the containers be inerted with both the dry sand and an inert gas. Figure 7 shows the packaging recommended for this purpose. A 16-gallon steel drum, qualified as a Type A container, is used to contain the penetrator fragments and the dry sand. This drum would be equipped with an inert gas inlet. Argon would be injected into the filled drum to displace the air. After all of the air is displaced, the cover would be sealed, and a slight over pressure of argon would be maintained in the container. The 16-gallon drum containing the penetrator fragments would be overpacked in a 30-gallon drum, qualified as a Type A container. Sand would be used as a buffer between the two drums. This is a conservative packaging concept but would be relatively inexpensive since it uses standard drums, and a relatively small number would be required. The drums would be reusable.

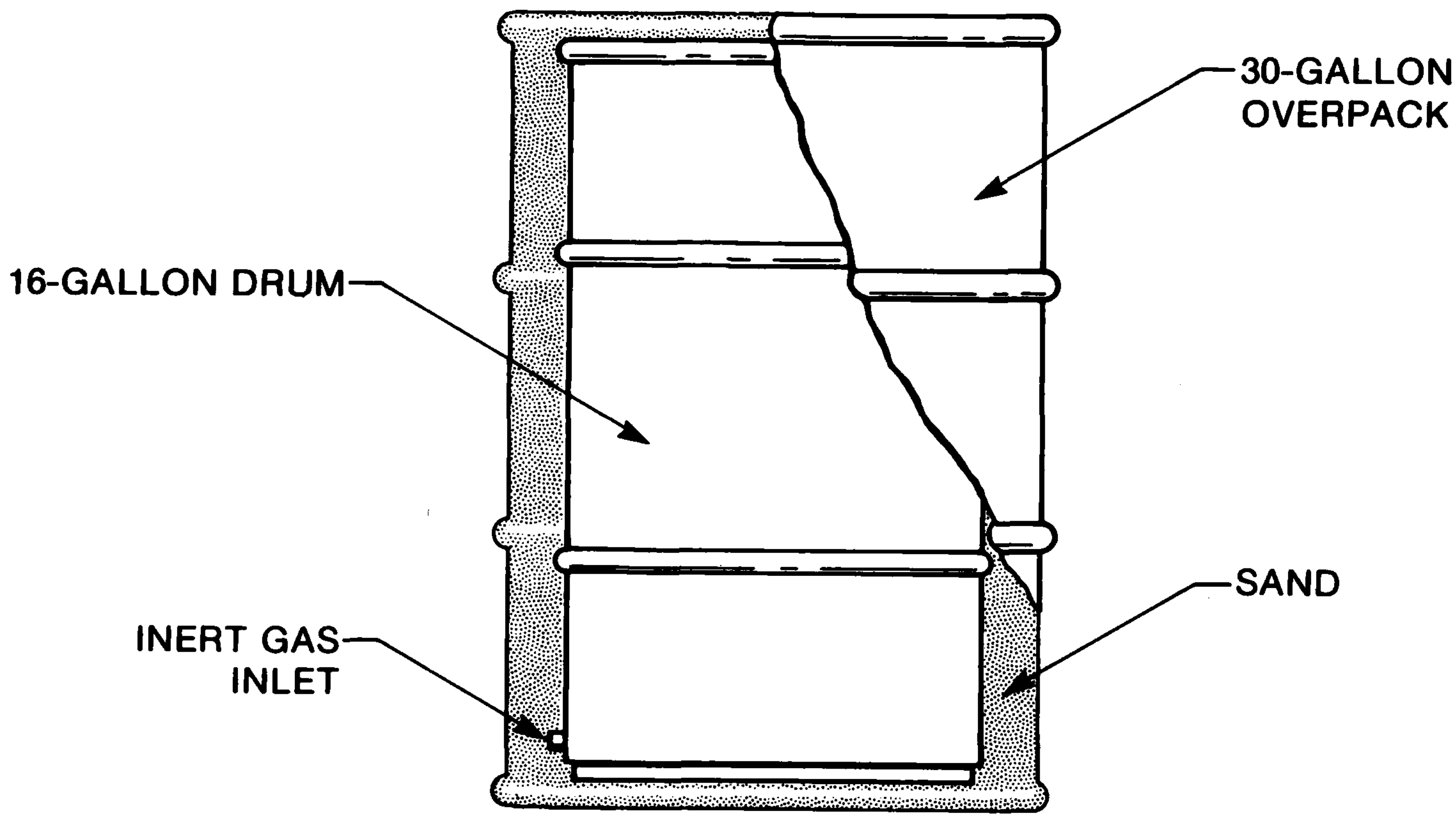

Figure 7. Package for Shipment of Penetrator Fragments

3. VALUE OF PENETRATOR FRAGMENTS

The penetrator fragments will have limited value to depleted uranium manufacturers. In the recycling demonstration project, considerable manual labor was required to segregate the uranium fragments from the aluminum windscreens and sand in preparation for melting. Depleted uranium has been readily available to manufacturers, and there are a number of sources of uranium scrap that are easier to recycle than the penetrator fragments.

For the current inventory of penetrators and for those generated in the near future, it is recommended that they be offered to uranium manufacturers at no cost other than shipping and the return of the shipping containers. Shipments should be allocated to various manufacturers to build an experience base in the handling and recycling of these materials. If the manufacturers show interest in the recycling of penetrator fragments, consideration can then be given to selling the uranium penetrator fragments on a competitive basis as a recoverable resource. There will also be savings due to the costs that would otherwise be incurred in the disposal of the penetrator fragments.

4. URANIUM CONCENTRATIONS

In the recycling program, the manufacturers will need to know the quantity of uranium contained in the drums. Sampling and analysis of the material could yield misleading results. Certain samples could contain relatively whole penetrators and other samples might be predominantly sand.

a. Calculation Method

A method has been developed to estimate the weight of uranium in a given drum using the size of the drum, the void volume and the gross weight. The derivation of this method is contained in Appendix C. This method utilizes the large differences in the specific gravity of uranium, sand and, where applicable, steel to calculate the volume and weight of each constituent. Since the uranium is primarily metal, no attempt is made to specifically account for the small quantity of uranium in the oxide form nor the aluminum wind screen material. The two equations for calculating the weight of uranium in a drum are as follows:

(1) Mixtures of Sand and Uranium Fragments

$$W_u = 1.1645\ W_t - 192.14\ V_t \tag{1}$$

(2) Mixtures of Sand, Uranium and Iron Fragments

$$W_u = 1168\ \frac{W_t - 165\ V_t}{1003 + 326\ (\frac{Ni}{Nu})} \tag{2}$$

(3) where:

W_u = Weight of uranium in given drum (lbs)

W_t = Weight of contents (lbs)

= Gross drum weight - weight of drum

V_t = Volume of solids (CF)

= Drum volume - unfilled volume - interstitial voids

N_i = Number of test penetrators in firing cycle

N_u = Number of uranium penetrators in firing cycle

b. Examples

The 54 drums of penetrators at the Eglin AFB have an average weight of 531 pounds. The drums weigh 15 pounds leaving a weight of contents of 516 pounds, W_t. The drums have an internal volume of 2.225 cubic feet. Assuming an overall void volume of 33 percent, the volume of solids, V_t, would equal 1.49 cubic feet. Less than 1 percent of the penetrators fired into the target were test (target practice) penetrators. Therefore, equation (1) can be used as follows:

$$\begin{aligned} W_u &= 1.165 \times 516 - 192.14 \times 1.49 \qquad (3) \\ &= 601.14 - 286.29 \\ &= 314.85 \text{ pounds uranium} \end{aligned}$$

Based on a weight of contents of 516 pounds, the material in the drums is about 61 percent uranium.

In the earlier firing cycles, larger numbers of test penetrators were fired. During the May 5, 1979 through January 22, 1980 firing cycles, 24,108 uranium penetrators and 23,765 test penetrators were fired into the target. The sieving operations on this material produced 75 drums of sand and penetrators having an average weight of 445 pounds. Using equation (2), the uranium content of the drums is calculated as follows:

$$W_t = 445 - 15 = 430 \text{ lbs.}$$

$$V_t = 1.49 \text{ CF}$$

$$\frac{N_i}{N_u} = \frac{23,765}{24,108} = 0.986 \qquad (4)$$

$$W_u = 1168 \quad \frac{430 - 165 \times 1.49}{1003 + 326 \times 0.986} \qquad (5)$$

$$= 1168 \frac{184.2}{1324.4}$$

$$= 162.4 \text{ lbs}$$

The concentration of uranium in these drums is about 37.8 percent.

5. EFFECTS ON DISPOSAL

With the present mode of operation using the sand target butt, the removal and recycling of the pentrators have a minimal effect on the quantities of contaminated material requiring disposal. In a typical firing cycle as previously shown in Figure 1, the volume of penetrator fragments is about 180 cubic feet compared to a total volume of 8665 cubic feet (contaminated sand: 8185 CF; HEPA filters: 300 CF; fragments: 180 cubic feet). The fragments constitute less than 1 percent of the total waste being generated.

If the uranium manufacturers are not interested in recycling of the uranium fragments, there is little motivation to continue separating the fragments other than to allow the sand to be reused.

The reuse of the sand could be increasing the quantity of contaminated material being generated. If the core of the target containing the penetrators could be selectively removed and not returned, the contamination of the majority of the sand used in the butt could be minimized and the useful life extended. This could significantly reduce the sand butt changes that produce the vast majority of the waste. Methods by which this could be accomplished are discussed in Section VI.

6. DISPOSAL OF SAND CONTAINING PENETRATORS

The selective removal of the target core results in sand containing concentrations of depleted uranium in the range of 10 percent. If the manufacturers are not interested in recycling of the uranium fragments, this material would be shipped as waste without segregating the uranium fragments. The concentration of this material is considerably less than the concentration of the sand containing the separated uranium fragments.

Provided that the sand is dry, it should be more than adequate to inert the uranium fragments. It may be possible to show that this material is non-pyrophoric to allow shipment as LSA. However, the use of 17H drums and shipment as Type A material will not significantly increase the cost. It should not be necessary to use cement and solidification to inert the material.

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SECTION V

CONTINGENCY PLANS FOR THE USE OF DEPARTMENT OF ENERGY FACILITIES

1. POLICY

The Memorandum of Understanding between the Department of Defense and the Department of Energy for the Disposal of Radioactive Waste requires the preparation of contingency plans for the use of DOE disposal facilities in the event that commercial disposal facilities become unavailable. Paragraph 3.1.4 of the Memorandum of Understanding contains the following provisions:

> "3.1.4 DOD agrees that each contract which involves the use of depleted uranium and the disposal of DUW and LLW shall include a contingency plan that the contractor will furnish to DOE and DOD. DOD will review and approve the plan, and DOE will have the right of disapproval (Section 4.0). The plan must list the steps the contractor will take in the event commercial disposal facilities become unavailable. The plan will state, as a minimum:
>
> (a) The amount (i.e., volume and activity) of DUW and LLW estimated to be generated in a specific period of time;
>
> (b) The availability of temporary on-site storage for DUW and LLW;

(c) A model time-phased action plan with the steps the contractor will take from the receipt of notice of potential unavailability of commercial disposal sites until the delivery of DUW and LLW by the contractor to a DOE-designated site; and,

(d) Specific procedures for notification and reporting in the event the contingency plan is implemented."

The Memorandum of Understanding deals with waste generated by contractors performing work on contracts with the Department of Defense. Even though the current agreement does not explicitly cover waste generated by government organizations and government facilities, such as Eglin AFB, it can be assumed that the same requirements will apply. As previously discussed, provisions should be made for contingency plans for military installations when the Memorandum of Understanding is renewed on July 1, 1987.

The current status of contingency plans was discussed in Section II.2.b of this report.

2. CONTINGENCY PLAN CONTENT

Based on the requirements stated in Paragraph 3.1.4 of the Memorandum of Understanding, the two contingency plans submitted by defense contractors and the Department of Energy comments on these contingency plans; a consolidated listing of the contents for contingency plan was compiled. The consolidated list of contents is as follows:

a. Projected Waste Volumes
b. Waste Characteristics, including exposure data
c. Available On-Site Storage Versus Waste Production
d. Characterization of Waste Per 40CFR261
e. Compliance with DOT Shipping Requirements
f. Packaging at Maximum Density
g. Compliance with Burial Site Requirements
h. Completion of Burial Compliance Worksheet
i. Completion of Solid Waste Burial Record
j. Structural Analysis of Special Containers
k. Handling Procedures and Use of Forklifts
l. Implementation Plan and Procedures
m. Points of Contact at Generator Facilities

3. IMPLEMENTATION PLAN AND PROCEDURES

Paragraph 3.1.4(d) of the Memorandum of Understanding requires specific procedures for notification and reporting in the event the contingency plan is implemented. The steps involved to implement the plan will generally consist of the following:

a. Determination of Non-Availability of Commercial Sites.
b. Notification of Procuring Contracting Officer.
c. Notification of State Licensing Authority.
d. Notification DOD Environmental Policy Directorate.
e. Notification of DOE by DOD.
f. Execution of Interagency Agreement.
g. DOE Designation of Disposal Site.
h. Notification of Contractor of Designated DOE Site.
i. Establish Contact with Designated Site.
j. Compliance with Requirements at Designated Site.
k. Utilization of Storage to Reduce Disposal Requirements.

l. Reporting of Incidents and Accidents.

m. Notification of Availability of Commercial Facilities.

n. Termination of the Use of DOE Facilities.

4. PREPARATION OF CONTINGENCY PLAN

Appendix D contains a contingency plan for Eglin AFB prepared in accordance with the guidelines discussed above. This contingency plan is based on waste continuing to be generated at the same quantities and of the same types as now being generated. In addition to the procedures required by the Memorandum of Understanding and the Department of Energy, this contingency plan includes the following initial actions prior to actual implementation.

a. Request the Department of Energy to designate specific DOE sites to receive waste from designated military installations and contractors.

b. Establish contact with key personnel at the designated DOE disposal facility.

c. Obtain guidelines for the acceptance of waste at each of the designated DOE sites.

d. Prepare procedures for processing, packaging and transportation to comply with DOE acceptance criteria.

e. Obtain concurrence of the designated DOE site on the processing, packaging, and transport procedures.

f. Advise the designated DOE site of conditions that could affect the quantities or activity levels of the waste or the procedures for processing, packaging and transport.

SECTION VI

DISPOSAL OF FUTURE WASTE

1. GENERAL

The Air Force must take action to reduce both the amount of waste generated and the amount of waste requiring off-site disposal.

The unit costs to dispose of waste are expected to increase significantly over the next few years due to a number of factors. These include:

a. The cost of siting new facilities will be much higher than for present disposal facilities.

b. The cost to license new facilities to meet the requirements of 10 CFR 61 will be greater than costs to license existing facilities.

c. New disposal facilities serving regional areas will handle less waste than present facilities.

d. Due to rising costs and shortages and uncertainties related to future burial sites, most generators have instituted volume reduction programs.

e. The unit costs for disposal will increase as volume is reduced since the fixed costs associated with the disposal facility will have to be amortized over a lower volume of waste.

f. Generators that do not reduce waste volume will end up paying a large percentage of the total cost of operating a disposal facility.

On-site disposal of waste having low levels of contamination is a method for reducing the volume of waste requiring off-site disposal.

2. VOLUME REDUCTION TECHNIQUES

The present method of testing depleted uranium penetrators inherently generates large quantities of wastes. A large amount of sand is subjected to contamination and eventually becomes waste that must be disposed off-site. Alternative approaches must be considered.

a. Firing Into Water

Figures 8a and 8b show two concepts that might be used to dissipate energy and collect the penetrators. Both are based on firing into water. The first approach (Figure 8a) uses an array of inclined armor plates to deflect the penetrators, causing them to lose their energy in a pool of water. The second method (Figure 8b) uses an inclined firing range to allow penetrators to be fired directly into water.

Water represents an ideal method of collecting the penetrators. First, the penetrators would undergo minimal damage. Periodically, the penetrators would be collected from the bottom of the pool for recycling. Very high recovery yield would be obtained. The penetrators would be readily recycled. The water would become contaminated, however, this contamination could be removed using filters and demineralizers. The total quantity of waste that would be generated would be at most 300 cubic feet per year.

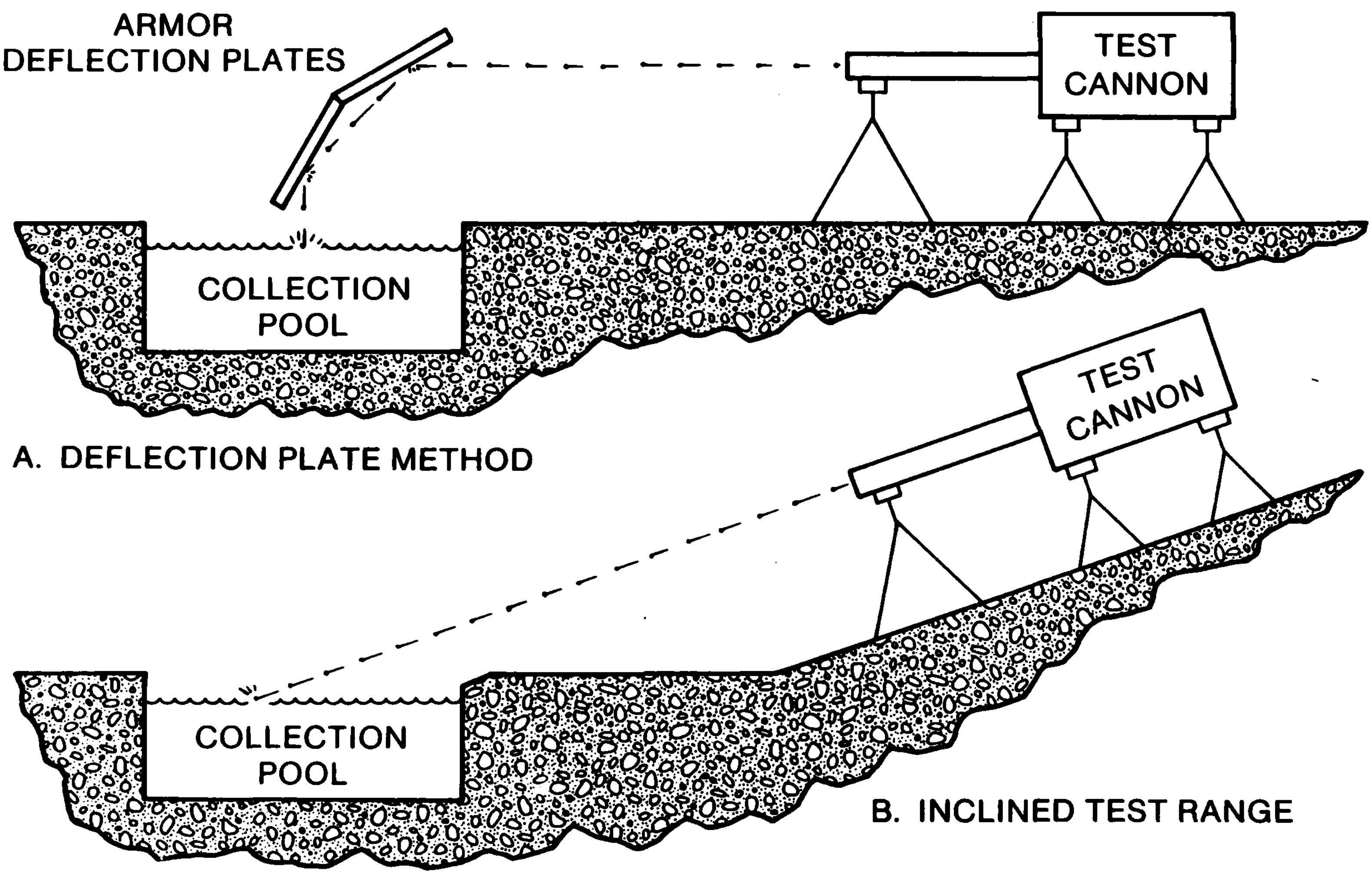


Figure 8. Concepts for Firing into Water

Compared to a sand target generating about 600 drums of waste per year (i.e., firing rate 50,000 rounds per year) or 4500 cubic feet, the potential savings in processing, packaging, transportation and disposal could be as much as $200,000 per year. The potential savings will increase as disposal costs escalate.

b. Sand Target Modification

Firing the penetrators into water would involve extensive modifications in the test facility. These modifications would be relatively expensive and would require several years to implement. Figure 9 shows what might be done to modify the present facility to reduce the quantity of waste being generated and the quantity of waste requiring off-site disposal.

As shown, a 6-foot diameter steel corrugated pipe is used to segregate the sand into which the penetrators are being fired from the bulk of the sand in the sand butt. The pipe would have 2-foot diameter risers to allow the contaminated air to be drawn from the target area and into the H.E.P.A. filters without contaminating the bulk of the sand located outside of the target area. These risers would also be used to fill the horizontal pipe with target sand. Vibrators would be used to fill the horizontal pipe to the top. An auger would be used to remove the sand from the horizontal pipe after each firing cycle. The auger may be permanently installed on the invert. Table 17 shows the volumes of sand and the concentrations of uranium associated with each firing cycle of 25,000 penetrators.

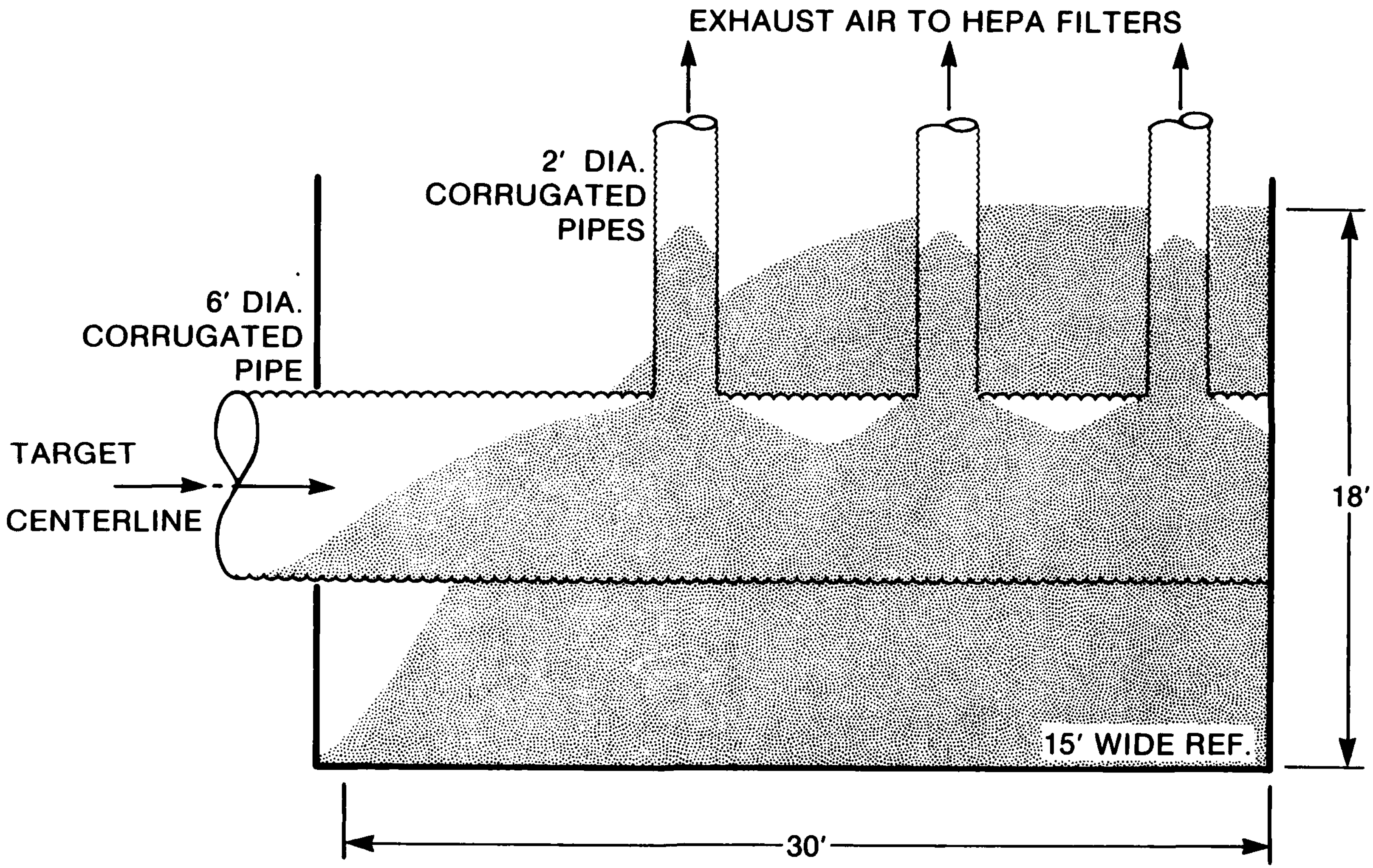


Figure 9. Segregated Sand Target Butt

TABLE 17. SAND VOLUMES AND URANIUM CONCENTRATIONS - SEGREGATED SAND TARGET BUTT

Butt Volume (at 15' x 18' x 30')	8,100 CF
Volume in Pipe (6' Dia. x 30')	848 CF
(3 At 2' dia. x 6')	56 CF
Volume per Firing Cycle	904 CF
Volume per Butt Change	7,196 CF
Weight of Sand in Pipe (at 110 lbs/CF)	99,400 lbs
Weight 25,000 Penetrators	16,520 lbs
Weight Percent Depleted Uranium	14.2 %
Recovery of Penetrators (at 60.5%)	10,000 lbs
Depleted Uranium Remaining	6,520 lbs
Weight Percent Uranium	6.2 %

c. Operational Aspects

Figure 10 illustrates how future operations would be conducted using the segregated sand butt approach. The operations are described as follows:

(1) Each firing cycle would consist of 25,000 penetrators having a total weight of 16,250 pounds or 2.5 curies of uranium.

(2) The penetrators would be fired into the central target butt core and penetrators, and the 900 CF sand would be removed by augering after each firing cycle.

(3) The 99,500 pounds of sand and 16,500 pounds of uranium would be sieved to recover about 10,000 pounds of depleted uranium.

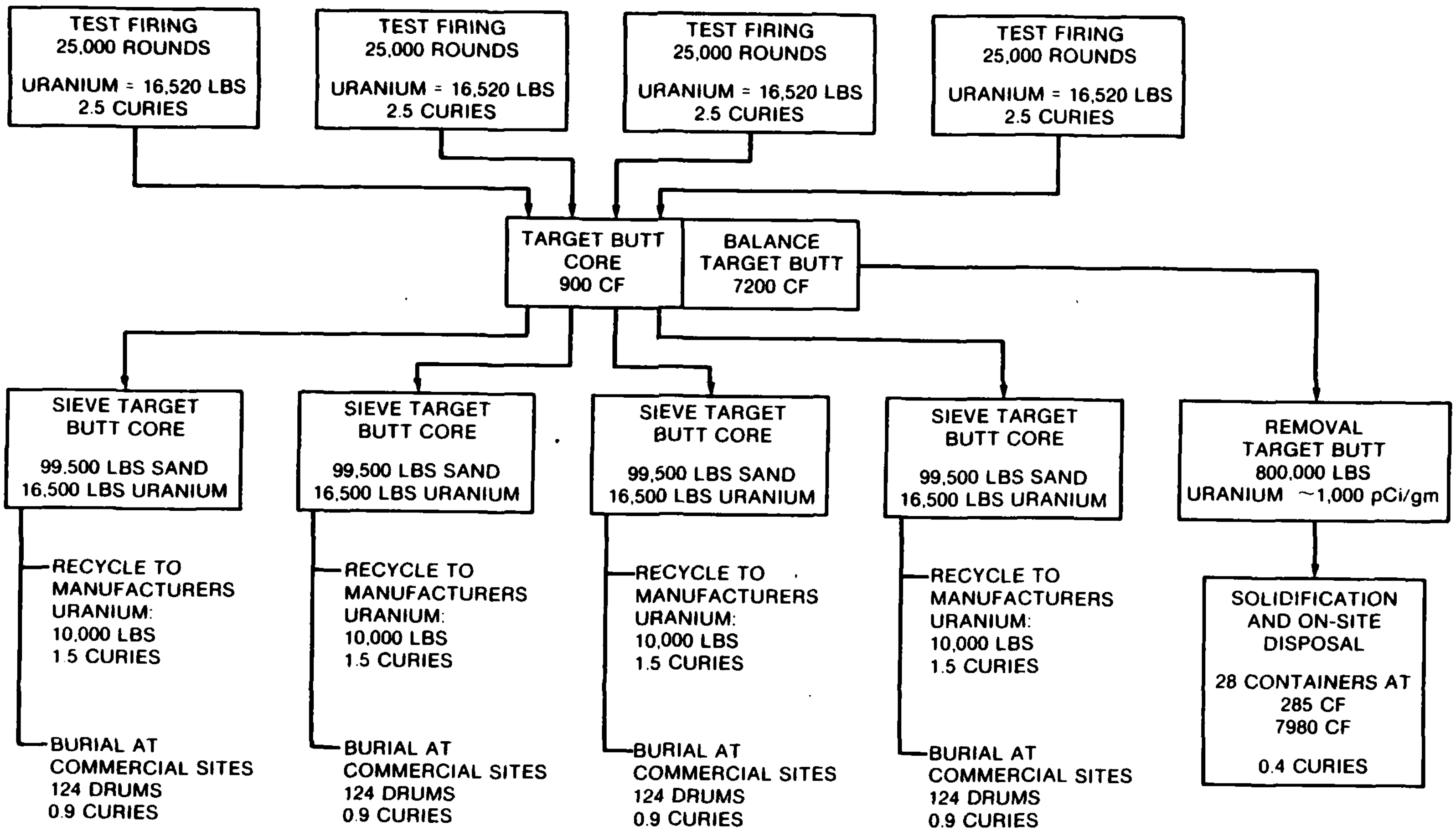


Figure 10. Future Waste Procesing and Disposal Operations

(4) The recovered uranium and associated sand will be shipped to uranium manufacturers for recycle in about 32 16-gallon inerted drums.

(5) The sand passing through the sieve will be processed and placed in 124 55-gallon drums and shipped to a commercial disposal site.

(6) The target butt core will be refilled with new sand for the next firing cycle.

(7) The uranium concentrations of the sand outside of the target pipe will be monitored. When the maximum concentrations approach 3,000 picocuries per gram, the entire sand butt and corrugated pipe will be replaced.

(8) The number of firing cycles between target butt replacements is expected to be greater than the four shown on Figure 10.

(9) Upon replacement of the entire sand butt, the contaminated sand will be mixed with cement and casted in high density cross linked polyethylene containers for burial on-site at Eglin AFB. The corrugated pipe will be cut into 6-foot sections and placed into the containers with the solidified contaminated sand.

The size of the horizontal pipe has been arbitrarily selected to be 6 feet in diameter. If a smaller pipe can be used, the quantity of sand requiring off-site disposal can be reduced.

3. PROCESSING AND PACKAGING

The uranium fragments will continue to be recovered using the mechanical sieve. The material will be wetted to control airborne contamination. The mixture of uranium fragments and sand will be dried, placed in 16-gallon drums and inerted with argon for shipment to a uranium manufacturer.

The sand passing through the sieve will be dried in the rotary dryer, and any potentially pyrophoric materials will be rendered non-pyrophoric. The material will be packaged into strong tight industrial containers or drums and shipped as LSA to a commercial disposal site or a Department of Energy site, if a commercial site is not available.

4. ON-SITE DISPOSAL

The segregated sand butt volume reduction technique is based on limiting the contamination of most of the sand to allow it to be buried on-site under a license granted under 10 CFR 20.302 (i.e., < 3,000 picocuries per gram insoluble, <1,000 picocuries per gram soluble).

Because of the extremely long half life of uranium 238 (i.e., 4.5 x 10^9 years), a high integrity container and a leach resistant waste form is recommended. It is proposed to solidify the contaminated sand with cement and place the mixture in containers of the type shown in Figure 11. These containers will be made of high density cross linked polyethylene. This is the material used for construction of high integrity containers. The containers are expected to have an effective life of at least 300 years in a burial environment. Containers of this type may well have a life of 1000 to 5000 years. In addition, the contaminated sand will be solidified

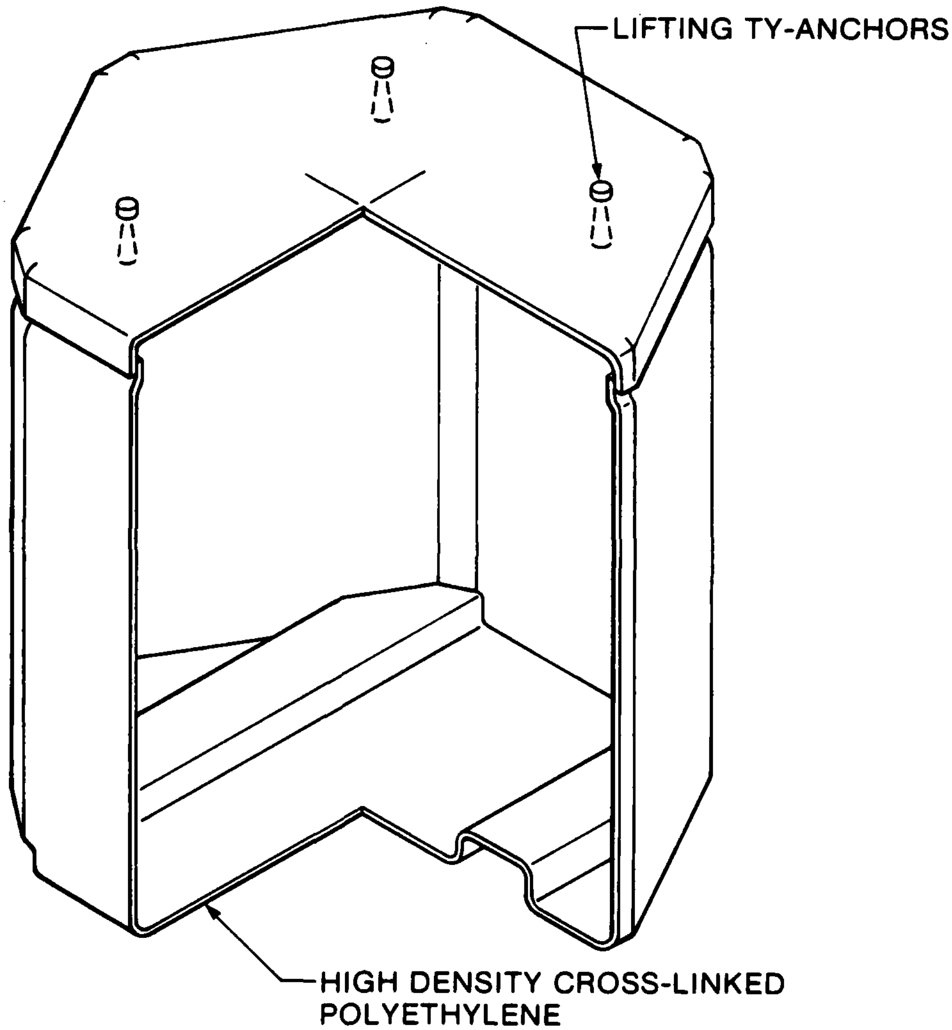


Figure 11. Polyethylene Form and Disposal Module

with cement using a water to cement ratio in the range of 0.35 to 0.4. This will provide a waste form with extremely low permeability (i.e., $< 10^{-8}$ cm per sec) and with a high leach resistance (i.e., leachability index > 7.0). The objective is to provide a waste form that will remain at least 1000 years in a burial environment without any significant deterioration. When deterioration of the waste form starts, it is expected to degrade gradually and to expose its contents over a period of at least 1,000 years.

The hexagonal shape of the disposal module was selected to provide waste packages that can be nested into a closely packed array as shown in Figure 12. This provides a structurally stable base that will minimize subsidence and provide support for a protective cover. As shown on Figure 12, the protective cover will consist of:

a. Earthen backfill to shape the cover
b. Gravel/bentonite infiltration barrier
c. Gravel drainage layer
d. Cobble/rubble biointrusion barrier
e. Earthen cover with native vegetation.

The cost of disposal using the disposal modules will be less than the present cost and very much less than the future cost of off-site disposal. Table 18 is a summary of the estimated cost of disposing of contaminated sand from one sand butt change (i.e., 7,980 CF) in 28 285-cubic foot disposal modules.

5. LICENSE APPLICATION

Appendix E contains a proposed application for a license amendment to allow on-site disposal of contaminated sand at

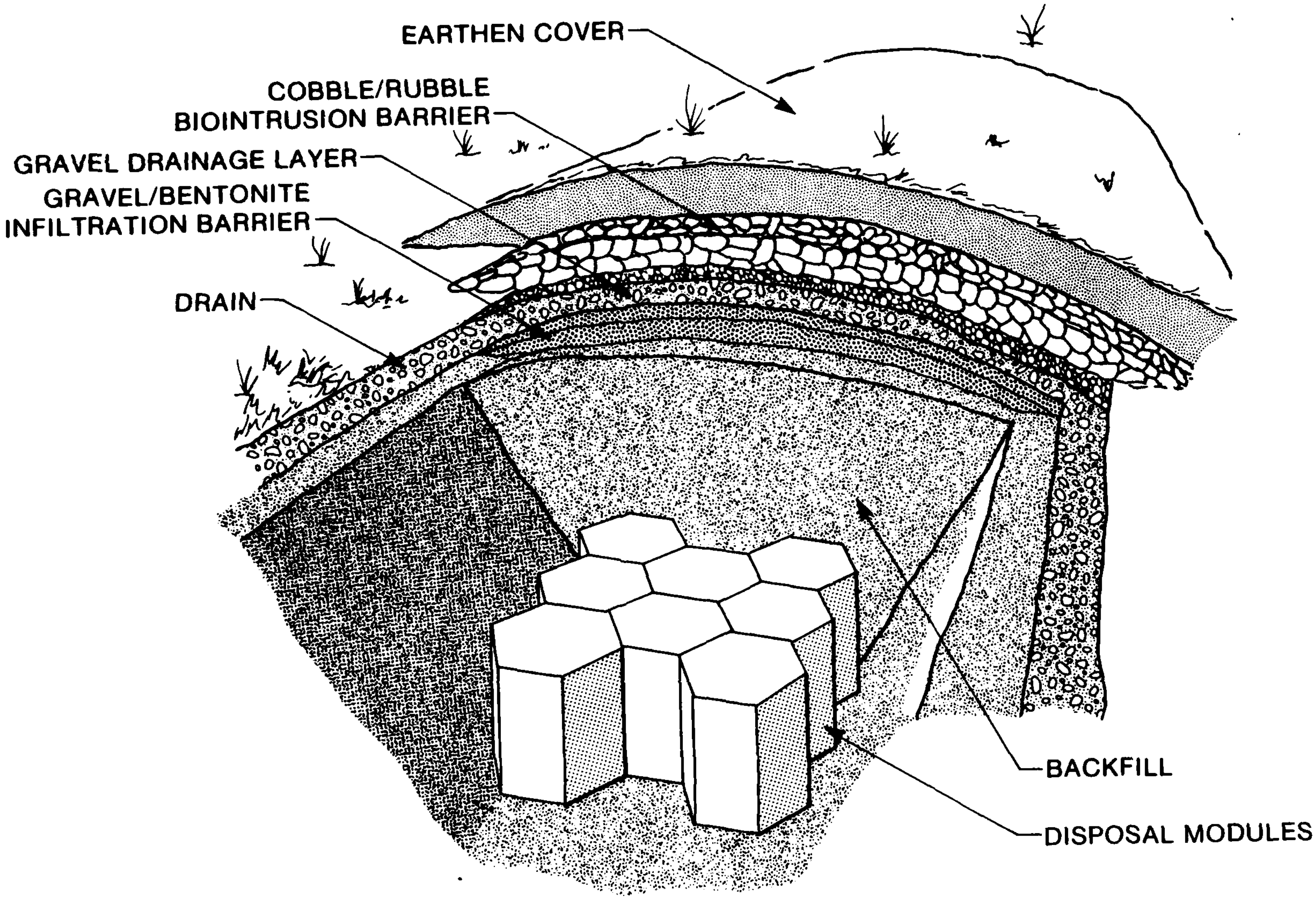


Figure 12. On-Site Disposal Facility

TABLE 18. ON-SITE DISPOSAL COST ESTIMATE*
(7,980 CF Contaminated Sand)

Container Cost 28 at $2500 Each	$70,000
Concrete 1:2.5 Mix, 0.4 WC	15,960
Labor and Equipment Rental	8,620
Trench Clearing and Excavation	4,680
Placement of Waste in Trench	700
Trench Backfill and Cover	30,500
Total Cost	$130,460
Unit Cost	$16.35/CF

*Does not include siting studies, environmental report, safety analysis and license application

Eglin AFB. The application would be made under 10 CFR 20.302.

This appendix contains a summary of the data compiled relative to the physiography, climate, hydrology, hydrogeologic setting, and hydrogeology of the proposed disposal site at Eglin AFB. Using information on the geochemistry of uranium, possible release scenarios and volumetric dilution ratios, a model is used to estimate the maximum dose result from the chronic ingestion of uranium over a fifty year period.

6. HEAVY METAL TEST FACILITY

In the next few years a heavy metal test facility will be constructed at the test site at Eglin AFB. This facility will be used for research, development, test and evaluation of depleted uranium and other high density munitions. Penetrators of new designs will be fabricated at the facility. A

test range will be available for testing these penetrators. It is planned to fire the penetrators into armor plate followed by fiberboard to collect the fragments and provide data on the dispersion of fragments. The following depleted uranium wastes will be produced at the Heavy Metal Test Facility.

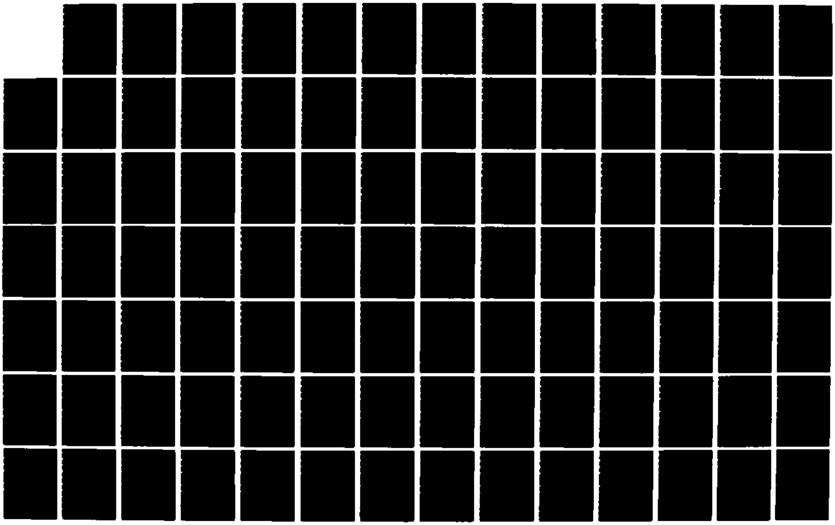
a. Cuttings, turnings, and chips
b. Grinder dust
c. Fabrication scrap
d. Reject penetrators
e. HEPA filters
f. Contaminated armor plate
g. Contaminated fiberboard target materials

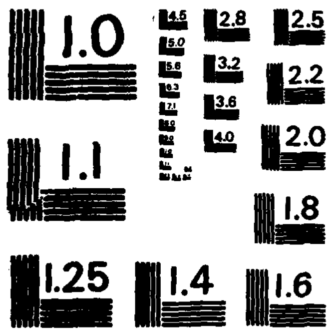
There are several methods by which the volume of waste can be reduced. These will include:

a. Oxidation of cuttings, turnings and grinder dust
b. Recycling of scrap and reject penetrators
c. Decontamination of armor plate
d. Incineration of fiberboard target material

The resultant wastes can be consolidated with the waste generated in the large scale testing of depleted uranium penetrators.

AD-A166 739 ALTERNATIVES FOR DISPOSAL OF DEPLETED URANIUM WASTE(U) 2/3
WESTINGHOUSE HITTMAN NUCLEAR INC COLUMBIA MD
C W MALLORY ET AL. NOV 85 AFATL-TR-85-78
UNCLASSIFIED F08635-84-C-0333 F/G 18/7 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SECTION VII

EVALUATION AND RANKING OF ALTERNATIVES

1. TECHNOLOGICAL STATUS AND RISKS

The alternatives presented in Sections III, IV, V, and VI of this report are being used or have been demonstrated with few exceptions. The areas where further research and development would be required are discussed below.

a. Processing of Potentially Pyrophoric Uranium Metal

Section II.3 and Section III.1.a discuss the considerations involved in making the waste non-pyrophoric and the savings that can be made by classifying the material as low-specific activity radioactive waste rather than as a pyrophoric material requiring inerting and shipment in Type A containers. The ability to render the waste non-pyrophoric by heating can be demonstrated with a few relatively simple and inexpensive experiments. The more difficult part of this task will be modifying the existing regulations to create a classification for Uranium Metal Non-Pyrophoric.

b. Volume Reduction Methods

Section VI.2 describes methods by which the volume of waste and the volume requiring off-site disposal could be reduced. None of these methods is now in use, and research and development work would be required to develop facilities that would make it possible to fire the penetrators into water. The segregated sand butt is less developmental and could be tried with minimal investment using the existing

facilities. However, it will require some time to determine the merits of this system.

Other methods of volume reduction should be investigated because of the significant savings that can potentially be made.

c. On-Site Disposal of Contaminated Sand

The techniques for on-site disposal of contaminated sand have not actually been demonstrated. The proposed polyethylene mold and disposal module would use fabrication methods similar to those used for the high integrity containers manufactured for low-level waste disposal. The methods proposed to create a highly leak resistant waste form represent a minor extrapolation of present practices.

There is little risk associated with the on-site disposal of sand having low-levels of contamination. First, the concentrations for insoluble uranium would be limited to 3,000 picocuries per gram (1,000 picocuries per gram for soluble material) which is the value allowed by the Nuclear Regulatory Commission. Secondly, the use of the polyethylene form combined with a highly leach resistant waste form will limit any possible release and exposure to any individual to a fraction of that allowed.

d. On-Site Disposal of All Waste

The disposal of all waste on-site would require the use of engineered disposal facilities. There are no engineered disposal facilities in the United States. Each of the alternative concepts presented has features that will require some development work. In addition, Eglin AFB is not the place to demonstrate new low-level radioactive waste disposal concepts.

Since the cost of on-site disposal using engineered facilities exceeds the cost of off-site disposal, the risks far exceed the benefit, and on-site disposal of all waste should not be given further consideration.

2. ECONOMIC CONSIDERATIONS

With respect to disposal of the current waste inventory, disposal at a commercial burial site as soon as possible is considered to be the only viable alternative. Virtually all of this waste exceeds the concentrations that might be disposed of on-site. Tests have indicated that it is not practical to remove additional uranium to the point that on-site disposal would be possible. At this time, the cost of processing, packaging, transportation and disposal of the present inventory will be approximately $1,280,000. This amount can potentially be reduced by as much as $250,000 if the material can be shipped by rail as low specific activity material. This will be a one-time effort. Because of the escalating cost of burial, the cost of disposal for the present inventory could increase as much as 50 percent in the next few years.

The long term cost of disposal will depend upon what can be done to reduce the volume of waste generated and the volume of waste requiring off-site disposal. If a water target can be developed, waste generation can potentially be reduced to about 300 cubic feet per year. The annual cost of disposal would initially be about $15,000 per year and would probably escalate to $60,000 at the end of 10-years (i.e., 15 percent per year). The 10-year disposal cost would be $350,000.

With the segregated sand butt and firing 50,000 penetrators per year with eight firing cycles per year, the waste generation for a 10-year period is shown in Table 19.

TABLE 19. WASTE GENERATION USING SEGREGATED SAND BUTT

Year	Fragments to Manufacturers (CF)	Sieved Sand (CF)	Butt Changes (CF)	Total Volume (CF)
1	160	1860	-	1860
2	160	1860	-	1860
3	160	1860	-	1860
4	160	1860	8000	9860
5	160	1860	-	1860
6	160	1860	-	1860
7	160	1860	-	1860
8	160	1860	8000	9860
9	160	1860	-	1860
10	160	1860	-	1860
Totals	1600	18,600	16,000	34,600

Based on an initial overall disposal cost of $50 per cubic foot (processing, packaging, transportation and disposal), disposal of all waste at commercial sites, and escalation at the rate of 15 percent per year, the disposal costs over a 10-year period are shown in Table 20.

TABLE 20. DISPOSAL COSTS WITH SEGREGATED SAND BUTT

Year	Disposal Cost ($/Cf)	Disposal Volume (CF)	Annual Cost ($)
1	$ 50.00	1,860	$ 93,000
2	57.50	1,860	106,950
3	66.13	1,860	123,000
4	76.04	9,860	749,750
5	87.45	1,860	162,660
6	100.57	1,860	187,060
7	115.65	1,860	215,110
8	133.00	9,860	1,311,380
9	152.95	1,860	284,490
10	175.90	1,860	327,170
Totals	-	45,760	$3,560,570

The current practice of recycling the sand and changing the sand target butt after each 100,000 penetrators results in the following volumes of waste and disposal costs, shown on Table 21.

TABLE 21. WASTE VOLUMES AND DISPOSAL COSTS WITH PRESENT SAND BUTT

Year	Disposal Cost ($/CF)	Waste Volume (CF)	Annual Cost ($)
1	$ 50.00	-	
2	57.50	8,000	$ 460,000
3	66.13	-	
4	76.04	8,000	608,320
5	87.45	-	
6	100.57	8,000	804,560
7	115.65	-	
8	133.00	8,000	1,064,000
9	152.95	-	
10	175.70	8,000	1,405,600
Totals		40,000	$4,342,480

The cost of disposal using the segregated sand butt can be further reduced by burying the 8000-cubic feet of sand generated every 4 years on-site. Assuming a current cost of $20 per cubic foot and a cost at year 4 of $30.42 and year 8 of $53.20 (i.e., escalation at 15 percent per year), the burial cost for this 16,000 CF of waste would be $668,960. This compares to a cost of off-site disposal of $1,672,320. This shows that the cost of disposal can be reduced by just over $1,000,000 by disposing of the contaminated sand at Eglin AFB. This would reduce the 10-year disposal cost to about $2,500,000. However, these savings would be reduced by future monitoring and administrative costs after closure of the facility.

As previously discussed, the recycling of penetrator fragments has little effect on disposal costs. Over a 10-year period, the savings in disposal costs would be about $186,000.

3. ENVIRONMENTAL IMPACTS

The processing of waste for off-site disposal results in little if any environmental impact on Eglin AFB. The processing operations can be closely controlled to virtually eliminate any airborne spread of contamination. No residual uranium remains to enter soil.

The on-site disposal of the contaminated sand is not expected to produce any adverse environmental impacts. The waste would be securely packaged into the disposal modules. The modules are designed to retain the waste for hundreds of years and thereafter to limit the release of the material at rates that will have nearly undetectable effects on the environment.

4. COMMITMENT OF RESOURCES

The future management of waste generated in the testing of armor penetrators will involve the commitment of significant resources. Resources will be required to implement some combination of the following alternatives.

a. Major modifications in the test range which will significantly reduce the quantities of waste generated.

b. Minor modifications in the test range to reduce quantities of waste generated and quantities requiring off-site disposal.

c. Licensing, construction and operation of an on-site disposal facility to allow disposal of contaminated sand at Eglin AFB.

d. Continue the present operation and bear the escalating costs of disposal at commercial disposal facilities.

The commitment of resources over the next 10 years under the last alternative will be about $4,500,000. This clearly indicates that some form of volume reduction is necessary to more effectively utilize financial resources.

The personnel resources of the Air Force are most effectively utilized through the continued use of off-site disposal of all waste. The primary mission of the Air Force is the research, development, test and evaluation of weapon systems. Involvement in waste disposal diverts personnel resources from their primary mission. The primary objective should be the development of facilities that will reduce the volume of the waste to a level where the cost of off-site disposal will be reasonable. If volume reduction can be achieved, this will also eliminate the need for any on-site disposal at Eglin AFB. This will relieve the Air Force from any long term commitment for the monitoring and custodial care of such a facility.

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REFERENCES

1. Hodge, H.C. and Voegtlin, C.; Pharmacolgy and Toxicology of Uranium Compounds, McGraw-Hill Book Company, Inc. 1949.

2. Friberg, L., Bordberg, G.F. and Vouk, V.B.; Handbook on the Toxicology of Metals, E/Sevier/North-Holland Biomedical Press 1979.

3. Casarett and Doull; Toxicology: The Basic Science of Poisons, MacMillian Publishing Co., Inc. 1980.

4. Spoor, N.L. and J.B. Hursh, Protection Criteria, Chapter 5 in Uranium-Plutonium Trans Plutonic Elements, Springer, Verlag 1973.

5. Memorandum of Understanding between the Department of Defense and the Department of Energy for the Disposal of Radioactive Waste, effective May 1, 1984.

6. Director, Environmental Policy, Office of Assistant Secretary of Defense letter dated September 26, 1984 to the Office of Defense Waste and By-product Materials Management, Department of Energy Program, Department of Energy letter dated November 18, 1984 to the Office of the Assistant Secretary of Defense.

8. Barnwell Waste Management Facility, Site Disposal Criteria; Chem-Nuclear Systems, Inc. Barnwell Office; Document No. S20-AD-010, Revision B dated November 28, 1983.

9. Nevada State Board of Health, Radioactive Material License, License Number 13-11-0043-02.

10. State of Washington, Radioactive Materials License, Number WN-I019-2.

11. U.S. Congress, House of Representatives Bill H.R. 3777.

12. U.S. Congress, Senate Bill S.1749.

13. U.S. Nuclear Regulatory Commission, Disposal or On-Site Storage of Residual Thorium or Uranium (either as Natural Ores or without Daughters Present) from Past Operations, Policy Issue SECY-81-576, dated October 5, 1981.

14. U.S. Nuclear Regulatory Commission, Branch Technical Position, Disposal or On-Site Storage of Thorium or Uranium Waste from Past Operations, Federal Register Notice 205 Volume 46, page 52061 dated October 23, 1981.

15. U.S. Nuclear Regulatory Commission, IE Information Notice No. 83-05; Obtaining Approval for Disposing of Very Low-Level Radioactive Waste - 10 CFR Section 20.302, SSINS No. 6835 dated February 24, 1983.

16. Waltz, Mark J., Depleted Uranium Tests Range Fragment Reclamation, Air Force Armament Laboratory, Final Report, AFATL-TR-82-49, July 1982.

17. Environics Branch, Air Force Armanent Laboratory letter, Task Two Alternatives, dated February 6, 1985.

APPENDIX A

ON-SITE DISPOSAL CONCEPTS
DESCRIPTION AND COST ESTIMATES

1. GENERAL

Eight (8) disposal unit concepts were selected for preliminary design and preparation of cost estimates. They are: shallow land burial, aboveground vaults, aboveground vaults with earthen cover, belowground vaults, mounded concrete bunkers, disposal trench with concrete canisters, disposal trench with pipe caissons, and augered caissons. It is assumed, that three disposal units will be constructed the first year to dispose of the current inventory of 3500 55-gallon drums. Thereafter, one (1) disposal unit designed to contain 1100 drums will be constructed each year for 20 years. The total number of disposal units constructed will be 23 which are designed to hold a total of 25,500 drums containing a total of 191,250 ft^3 of contaminated sand.

Two (2) alternative operating concepts utilizing concrete canisters are also described in this report. In these alternate operating concepts, the concrete canister is used for interim storage of drums or contaminated sand for 4 years, and then the 4-year inventory of concrete canisters are buried in one disposal unit. The total number of disposal units constructed will be six which are designed to hold the same number of drums or contaminated soil as stated above.

2. DISPOSAL UNIT DESCRIPTION

The following is a brief description of each disposal unit concept, and the design features of the various concepts are

described and compared to shallow land burial. Table A-1 summarizes the design features of each disposal unit concept.

a. Shallow Land Burial

The shallow land burial trench, Figure A-1, is approximately 18 feet wide by 100 feet long by 10 feet deep and is designed to contain 1100 55-gallon steel drums stacked three high. The land around each trench will be cleared and the trench will be excavated. The bottom of the trench will be graded to provide at least a 1 percent slope toward one end for drainage and a drain sump will be placed at the low end. A layer of gravel with a compacted clay surface will be placed on the trench bottom to allow for drainage and the passage of drum handling equipment. Once the trench is dug and the bottom prepared, the trench will be filled with 55-gallon steel drums. The spaces between the drums will be backfilled with gravel to allow for drainage and to minimize subsidence of the trench cover.

The trench cover is an engineered structure which is designed to minimize surface water infiltration into the disposal trench. The cover consists of six functional layers of material which are sloped 6 percent to increase runoff and minimize infiltration. The 2-foot thick compacted clay infiltration barrier provides a continuous barrier over the entire waste disposal area. A sand/gravel drainage filter layer is placed over the clay infiltration barrier to provide drainage. The sand layer functions as a filter to minimize the intermixing of the coarse gravel with the finer clay material. The sand layer also retains sufficient moisture at the infiltration barrier surface to prevent dehydration and subsequent cracking of the barrier which could potentially reduce its effectiveness. The 2-foot thick layer of cobble

TABLE A-1. DESIGN FEATURES OF DISPOSAL CONCEPTS

DISPOSAL UNIT CHARACTERISTICS	SHALLOW LAND BURIAL	ABOVEGROUND VAULT	ABOVEGROUND VAULT WITH COVER	BELOWGROUND VAULT	MOUNDED BUNKER	CONCRETE CANNISTER	PIPE CAISSON	AUGERED CAISSON
CONTROL SURFACE WATER INTRUSION	*	*	*	*	*	*	*	*
BARRIER TO RADIONUCLIDE MIGRATION	*	*	*	*	*	*	*	*
CONTROL TRENCH CAP SUBSIDENCE		NA	*	*		*	*	NA
CONTROL GROUND WATER INTRUSION	*	*	*	*	*	*	*	*
PLANT/ANIMAL INTRUSION BARRIER	*	*	*	*	*	*	*	*
INTRUDER PROTECTION - STRUCTURAL		*	*	*		*	*	*
SECONDARY CONTROL OF SURFACE WATER INTRUSION			*	*		*	*	*
SECONDARY CONTROL OF GROUND WATER INTRUSION			*	*	*	*	*	*
NOT VULNERABLE TO EXTERNAL EVENTS	*			*	*	*	*	
LONG-TERM STRUCTURAL INTEGRITY	*		*	*	*	*	*	
ADDITIONAL INTRUSION BARRIERS			*	*		*	*	
SECONDARY BARRIER TO RADIONUCLIDE MIGRATION			*			*	*	
ISOLATES WASTE FROM EROSION OR MASS EARTH MOVEMENT		*	*	*		*	*	*
DOES NOT REQUIRE LONG-TERM STRUCTURAL MAINTENANCE	*		*	*	*	*	*	
NOT SUSCEPTIBLE TO SEISMIC EVENTS	*					*	*	

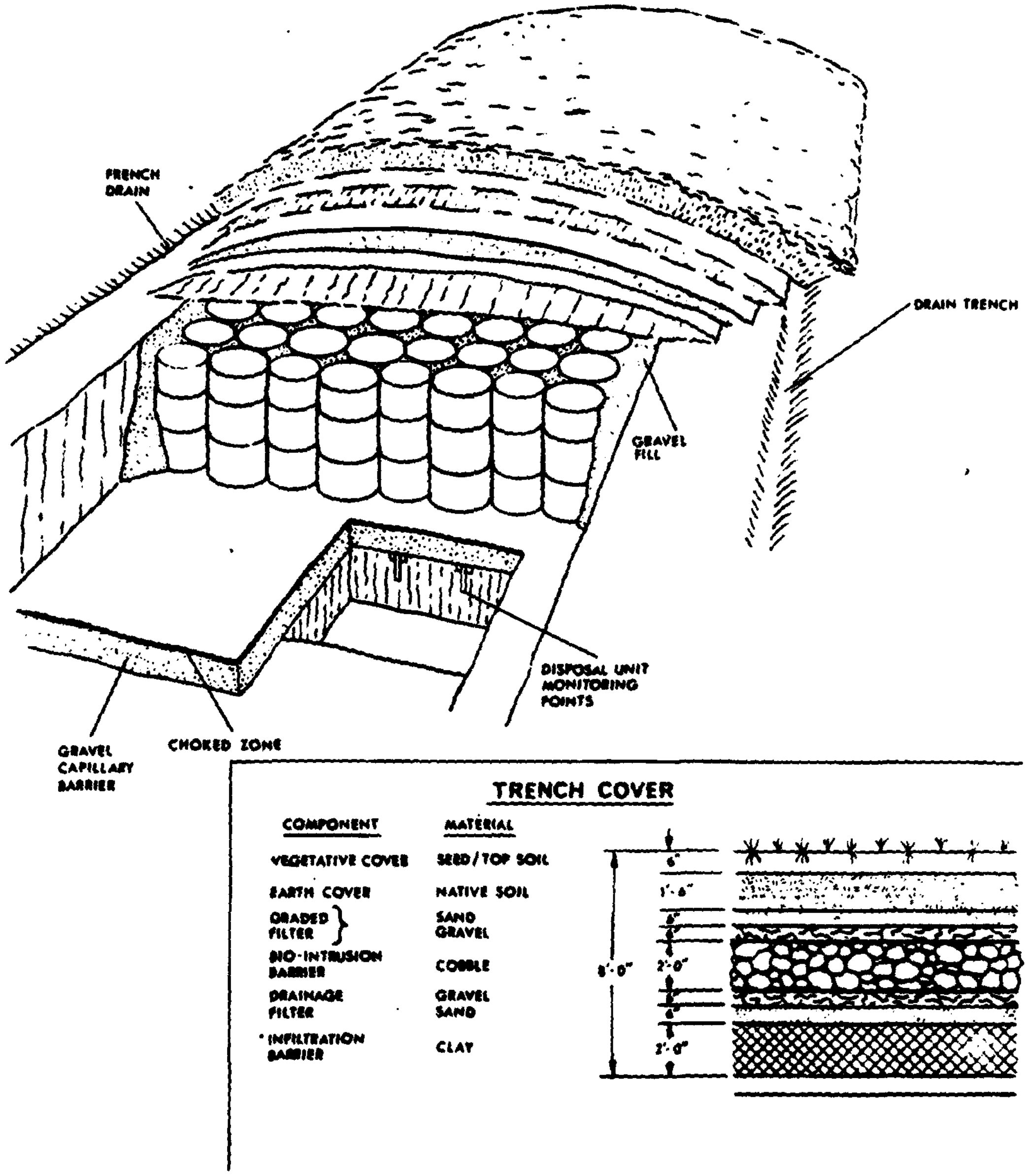

Figure A-1. Improved Shallow Land Burial

forms a bio-intrusion barrier for protection of the clay infiltration barrier from deep rooting plants and burrowing animals. Above the cobble layer, a sand/gravel grade filter layer is placed to minimize silting and root penetration into the cobble. The sand layer of the graded filter will also provide a lateral transport path for moisture to flow away from the trench area by means of the wick effect. The graded filter layer drains to the drainage trenches, which border the disposal trench, and permit moisture to flow away from the disposal trench area. A 1.5-foot thick earth cover overlays the graded filter layer. The earth cover is sufficiently thick to provide for freeze/ thaw protection to the deeper layers. Also, the thick earth cover provides sufficient water storage capacity for the needs of the vegetation which control erosion of the trench cover. Surface runoff from the cover is collected in trench drains which border the cover. The drains move the water from the trench area and lead to diversion ditches which control surface water flow for the complete disposal site.

During the 20-year site operating period, the 23 shallow land burial units will be constructed in two parallel rows. With a 6 percent slope to the cover, the area required for each shallow land burial unit is 285 feet by 360 feet. Using a 20-foot separation between burial unit covers to allow for site drainage, a site buffer zone of 200 feet, and a 200 feet, separation between rows, the complete site area will be 1320 feet by 4000 feet or 121 acres.

b. Aboveground Vault

The aboveground vaults, Figure A-2., are constructed from reinforced concrete. They are designed to withstand the forces due to natural occurrences such as hurricanes, tornados,

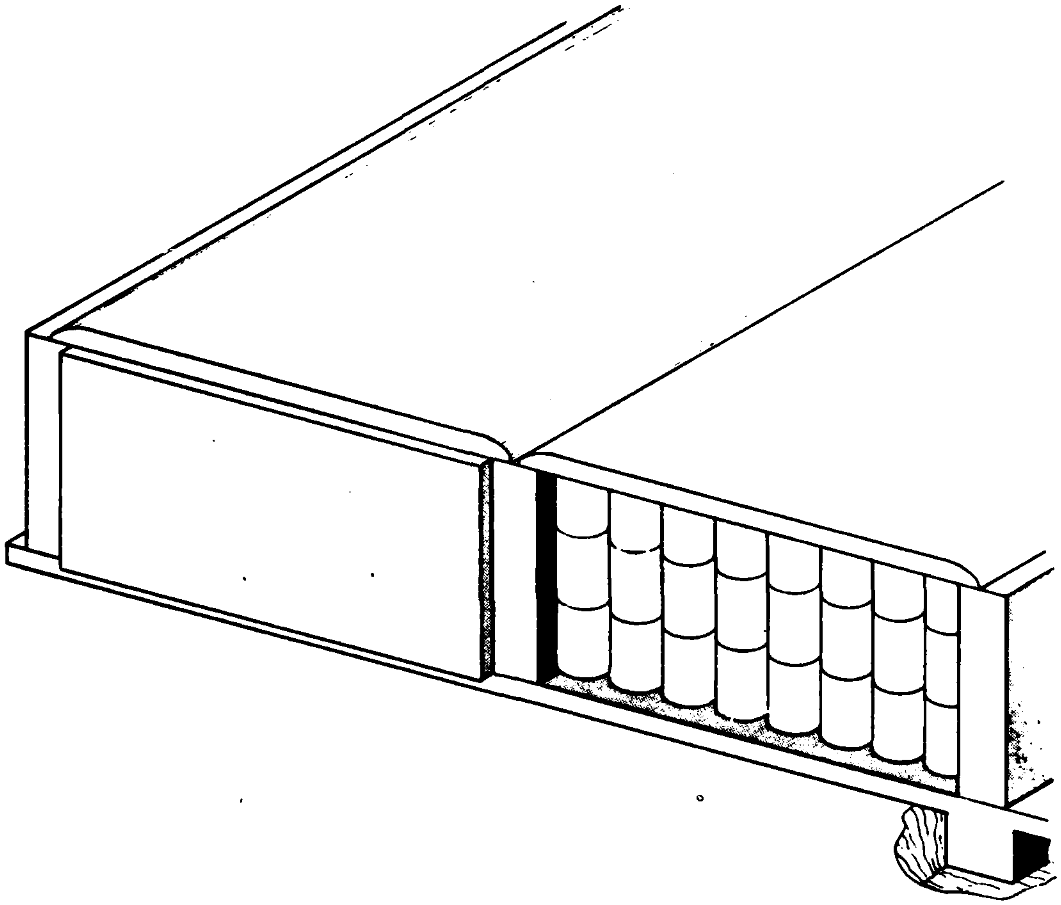

Figure A-2. Above Ground Vault

and seismic events. Each vault is approximately 17 feet wide by 94 feet long by 9 feet high and will hold 1100 55-gallon steel drums.

The site area will be cleared and graded, and trenches for the vault footings and sumps will be dug. The complete vault structure consisting of footings, floor slab, walls, and roof will be cast in place in order to keep the number of joints to a minimum, and to provide a fixed structure which is able to withstand all lateral forces. The floor will have a central drain leading to a monitoring sump. The vault roof will be sloped 1/8 inch per foot, and collection gutters will be formed into the long sides of the roof to allow for drainage. It is anticipated that the drums will be placed in the vault with a fork lift. After all the drums are placed in the vault, the vault will be sealed by grouting a door slab in place. The common wall between vaults will be sufficiently thick to support both roofs, and as one wall and roof are cast, reinforcement will protrude from the wall to permit attachment of the other roof at a later date. In this manner, a row of vaults can be continuously formed throughout the site operating period. Twenty-three vaults will be constructed. With a site buffer zone of 200 feet, the complete site area will be 500 feet by 825 feet or 4.5 acres.

Aboveground vaults offer several advantages over shallow land burial as a means for disposal of low-level waste. The waste drums are more readily retrievable. Since the vaults are at grade level, ground water intrusion does not present a problem. Surface water can be diverted from the vault area. The physical condition of the vaults is visually observable, and repairs to the structure can be easily made. Also the vaults require less land area than shallow land burial.

The main disadvantage of aboveground vaults for very long term storage or as permanent disposal units is the question of the structural durability of reinforced concrete. Also, aboveground vaults are susceptible to external events which in the very long term could lead to the possibility of the vault breaching and releasing its contents in a concentrated form. To overcome these disadvantages, an aboveground vault with earthen cover is investigated.

c. Aboveground Vault with Earthen Cover

To convert the aboveground vault as described above from a long term storage to a permanent disposal concept, an earthen cover is placed over the vault during the site closure period. The proposed cover, Figure A-3, is the same design as described in the shallow land burial section of this description.

During the operation period, the vaults are constructed and filled on a yearly basis as described above. At closure of the site, the area around the vaults is backfilled with native soil and the soil compacted. The six layered cover is then constructed over the vaults. French drains and drainage ditches are also constructed to control surface runoff from the cover. Using a 6 percent slope to the cover and a 200-foot site buffer zone, the complete site area will be 1100 feet by 1425 feet or 36 acres.

The cover protects the vault from external events. It also provides an additional barrier to radionuclide release should the vault breach in the future. The vault/cover combination provides additional barriers to inadvertent human intrusion and to water infiltration. Also the vault minimizes potential subsidence of the cover.

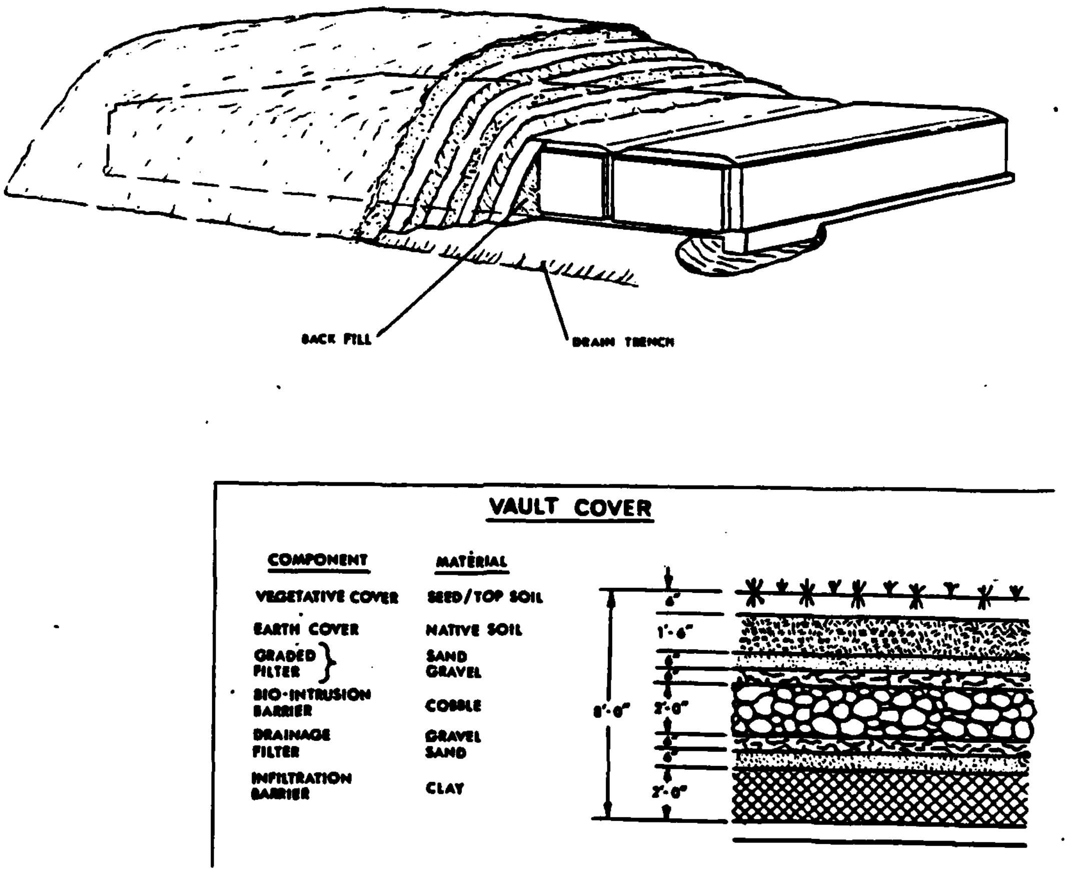

Figure A-3. Aboveground Vault with Cover

d. Belowground Vault

The belowground vault, Figure A-4, is similar in concept to the aboveground vault with cover and provides many of the same advantages. The site area is cleared and excavated to accommodate a vault with inside dimensions of 17 feet wide by 94 feet long by 9 feet high. The reinforced concrete footings, floor slab, and walls are cast in place. Since the vault is open to the weather during its construction and filling stages, provisions for water drainage and collection will be made by sloping the floor towards one end and installing a collection sump at the low end. The vault is filled with 1100 55-gallon steel drums stacked three high by lowering them from the top using a small mobile crane. After the vault is filled with drums, a lift slab reinforced concrete roof is lowered in place, and all joints are grouted. The vault is then covered with the six layer trench cover described in the shallow land burial section of this description.

During the 20-year site operating period, the 23 vaults will be constructed in two parallel rows. With a 6 percent slope to the cover, the area required for each vault is 285 feet by 360 feet. Using a 20-foot separation between vault covers to allow for drainage, a site buffer zone of 200 feet, and a 200-foot separation between rows, the complete site area will be 1320 feet by 4000 feet or 121 acres.

The belowground vault concept requires approximately the same land area as shallow land burial. The vault structure provides an additional barrier to inadvertent human or plant and animal intrusion, ground water infiltration, and radionuclide migration. The belowground vault is less visually obtrusive than the aboveground vault, and is less

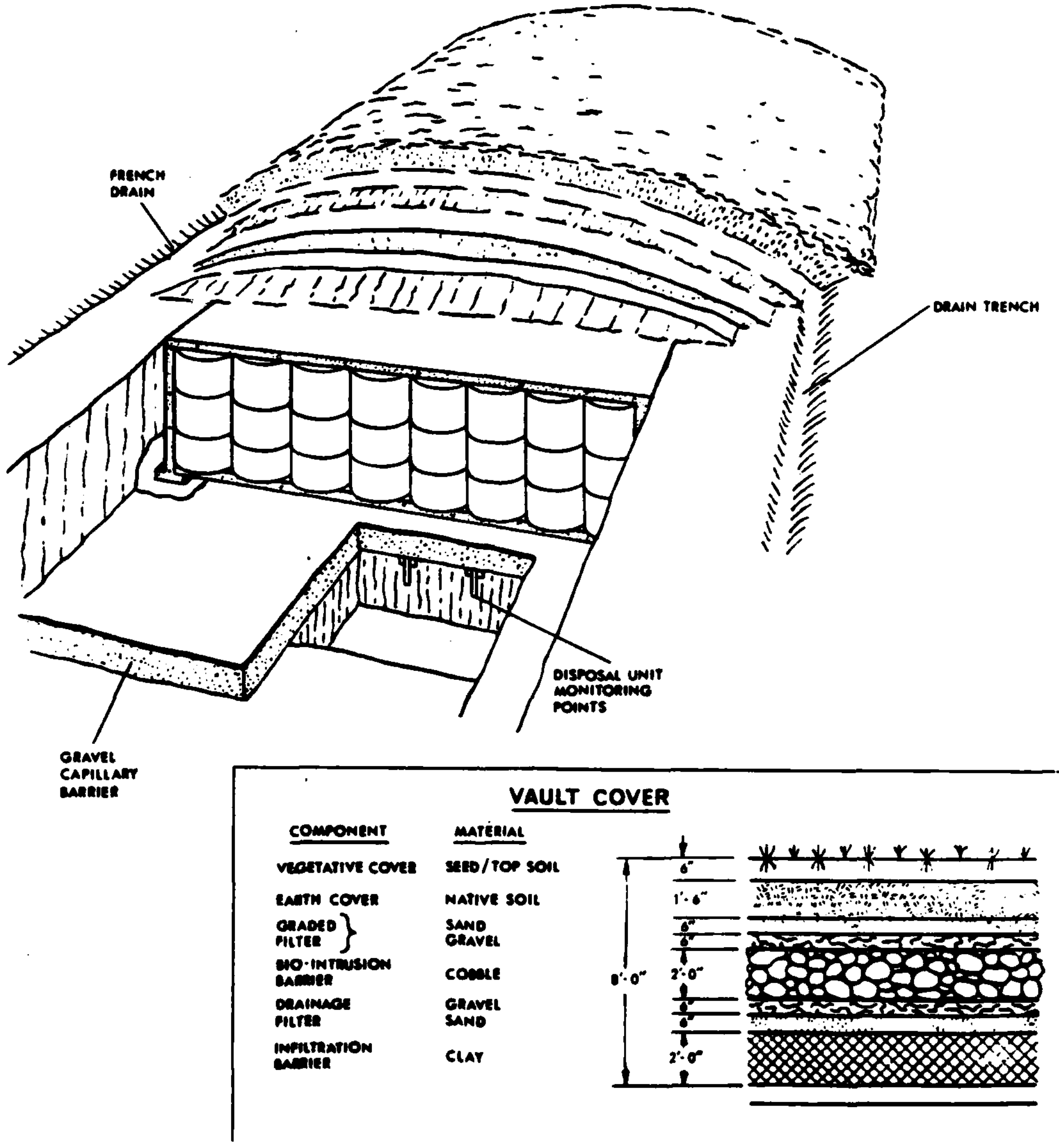

Figure A-4. Belowground Vault

susceptible to external events. The vault also provides support to the layered cover and minimizes the problems of cover settlement.

The belowground vault requires more land area than the aboveground vault concepts, and the waste is not as readily retrievable. The vault is more susceptible to seismic damage than shallow land burial. Also, the vault would be susceptible to damage by corrosive soils.

e. Mounded Concrete Bunker

A concept similar to the mounded concrete bunker design, Figure A-5, described in this report is currently being used in France at Le Centre De La Manche for the disposal of low-level radioactive wastes. The concept is similar to the belowground vault except that a vault roof is not provided.

The site is cleared and excavated to accommodate an open vault with inside dimensions of 17 feet wide by 90 feet long by 6 feet high. The footings, floor slab, and vault walls are cast in place reinforced concrete. As with the belowground vault, the floor is sloped toward one end for drainage, and a collection sump is provided. The 1100 drums are placed with a small mobile crane. The drums are stacked two high at the walls and up to four high in the center of the bunker. Grout is poured into the void spaces between the drums, and a 1-inch thick layer of gunite is sprayed over the outer surface of the drums to form one solid waste mass. The mass is used to provide support to the earthen cover. The waste extending above grade level is backfilled with native soil and compacted. The six layer cover, described previously, is then formed over the bunker.

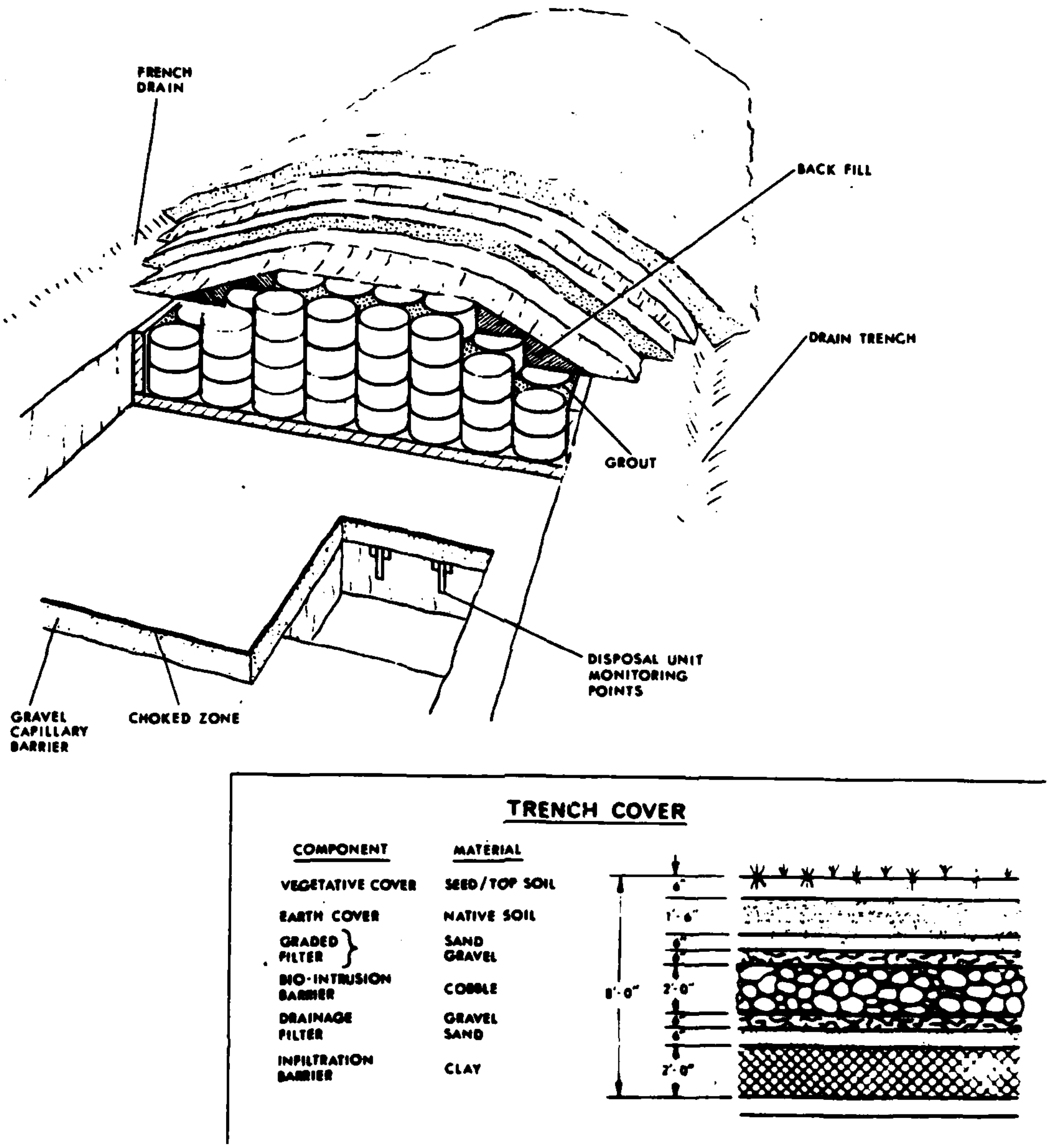

Figure A-5. Mounded Concrete Bunker

The 23 bunkers constructed during the site operating period will be placed in two parallel rows. With a 6 percent slope to the cover, each bunker will require an area 485 feet by 556 feet. Using a 20-foot separation between bunker covers to allow for site drainage, a site buffer zone of 200 feet, and a 200-foot separation between rows, the complete site area will be 1700 feet by 6400 feet or 250 acres.

The mounded concrete bunker requires a shallower excavation than shallow land burial or the belowground vault, and it is therefore more suitable in areas which have a high ground water table. Grouting the void spaces between drums provides additional support to the layered cover. The concrete pad and walls make the mounded concrete bunker less susceptible to ground water infiltration than shallow land burial.

The mounded concrete bunker design requires the largest site area of all the concepts considered. Special drains must be constructed to prevent the bunker from filling with infiltrating water. The bunker is more susceptible to seismic events than shallow land burial, and the gunite layer does not present a significant additional barrier to inadvertent human or plant and animal intrusion.

f. Concrete Canister

The concrete canister concept, Figure A-6, is used in conjunction with the shallow land burial trench and six layered trench cover described previously. Fourteen 55-gallon steel drums are packaged in each concrete canister, and 79 modules are required to contain the yearly production of 1100 drums. The drums are placed in the concrete canisters and grout is poured into the module to fill the void spaces

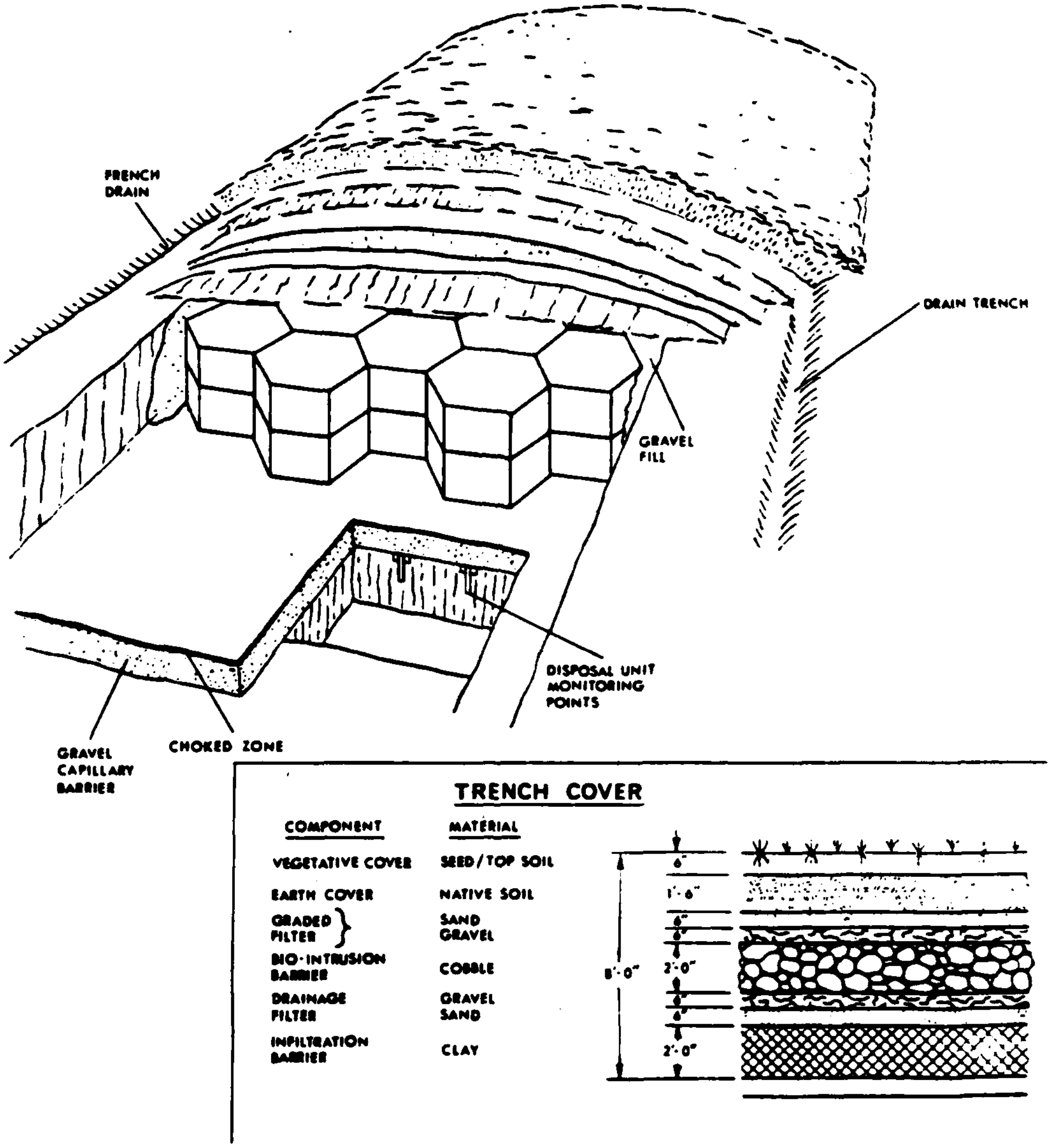

Figure A-6. Concrete Canister

between the drums and to secure the reinforced concrete canister lid which is then placed on top of the module. The modules can then be transported to the burial trench and lowered into place, or the canisters can be used as interim storage for several years' production of drums so that an economy of scale could be realized. Cost estimates for both alternatives are presented in this report.

The option of disposing the concrete canisters on a yearly basis requires a burial trench 43 feet wide by 61 feet long by 15 feet deep to contain 79 canisters. The current inventory of drums requires three 43-foot wide by 69-foot long trenches each containing 84 modules. The canisters are lowered into the trench with a mobile crane, and the void spaces between the modules are backfilled with gravel. The six layer cover is then constructed over the burial tench. The 23 concrete canister disposal units constructed during the 20-year site operating period will be arranged in two parallel rows. With a 6 percent slope for the cover, the trench cover area for each unit is 310 feet by 326 feet. Using a 20-foot separation between covers for drainage, a 200-foot site buffer zone, and a 200-foot separation between rows, the complete site area will be 1250 feet by 4360 feet or 125 acres.

Alternatively, the current inventory of drums can be disposed of in one trench 43 feet wide by 172 feet long containing 250 modules. The concrete canister can be used for interim storage of drums. In this option, the contaminated sand is processed yearly, placed into 55-gallon steel drums, and the drums placed and grouted into the concrete canisters. The canisters are stored up to 4-years, and then the 4-year inventory of canisters, 316, is buried in one disposal trench which is 43 feet wide by 234 feet long by

15 feet deep. During the 20-year site operational period, six disposal units are constructed. With a 6 percent slope for the trench cover, the trench cover area is 310 feet by 500 feet. The six disposal units are arranged in a row with a 20-foot separation between units. With a 200-foot buffer zone around the disposal units, the complete site area will be 900 feet by 2360 feet or 49 acres.

As an additional alternative, the contaminated sand can be processed directly in the concrete canister. A special concrete canister with a mixer blade assembly is supplied. Approximately 125 cubic feet of contaminated sand is placed in the canister, cement and water are then added, and the mixer turned on. The waste is thereby solidified within the concrete canister. As in the previous alternative, the current inventory of drums are placed in canisters and buried. Then the yearly production of sand is solidified in the canisters and the canisters are stored up to 4-years. Then the 4-year inventory of canisters, 264, is buried in one disposal trench which is 43 feet wide by 186 feet long by 15 feet deep. Six disposal units are also constructed during the site operational period. With a 6 percent slope for the trench cover, the cover area is 310 feet by 450 feet. The six disposal units are again arranged in a row with a 20-foot separation between units. With a 200-foot buffer zone around the site, the site area will be 850 feet by 2360 feet or 46 acres.

Grouting or solidifying the waste within the concrete canister fills the void spaces and creates a solid concrete monolith to support the trench cover. The canister provides additional barriers to ground water and to inadvertent human or plant and animal intrusion. The canisters will form a tightly packed array within the trench, and the canisters are better able to resist seismic events than solid

monolithic vaults. The canisters are retrievable and easily identified. The waste within the canister will remain isolated even if erosion or mass earth movement uncovers the disposal trench.

The concrete canister concept requires a larger and deeper trench than shallow land burial. Also burying concrete canisters on a yearly basis requires a slightly greater site area than shallow land burial.

g. Concrete Pipe Caissons

The pipe caisson concept, Figure A-7, is similar to the concrete canister design in that the drums are placed and grouted within a reinforced concrete culvert. The site is cleared and a 26 feet wide by 90 feet long by 15 feet deep trench is excavated. The trench design is the same as the one described for shallow land burial. For a yearly production of 1100 drums, 31, 8-foot diameter by 15-foot high concrete culverts are required. The culverts are lowered vertically into the trench, and a 6 inch thick layer of grout is poured into the bottom of the culverts to form a base. The waste drums are lowered into the culverts and are stacked four high. Grout is then poured into the culverts to fill the void spaces between the drums and to form a solid cover on top of the drums. Gravel is used to backfill the spaces between the culverts, and the six (6) layer cover is constructed over the disposal trench.

With a 6 percent slope to the trench cover, the cover area for each trench is 292 feet by 356 feet. The 23 trenches constructed during the site operating period are arranged in two parallel rows with a 200-foot separation between rows. Using a 20-foot separation between the covers

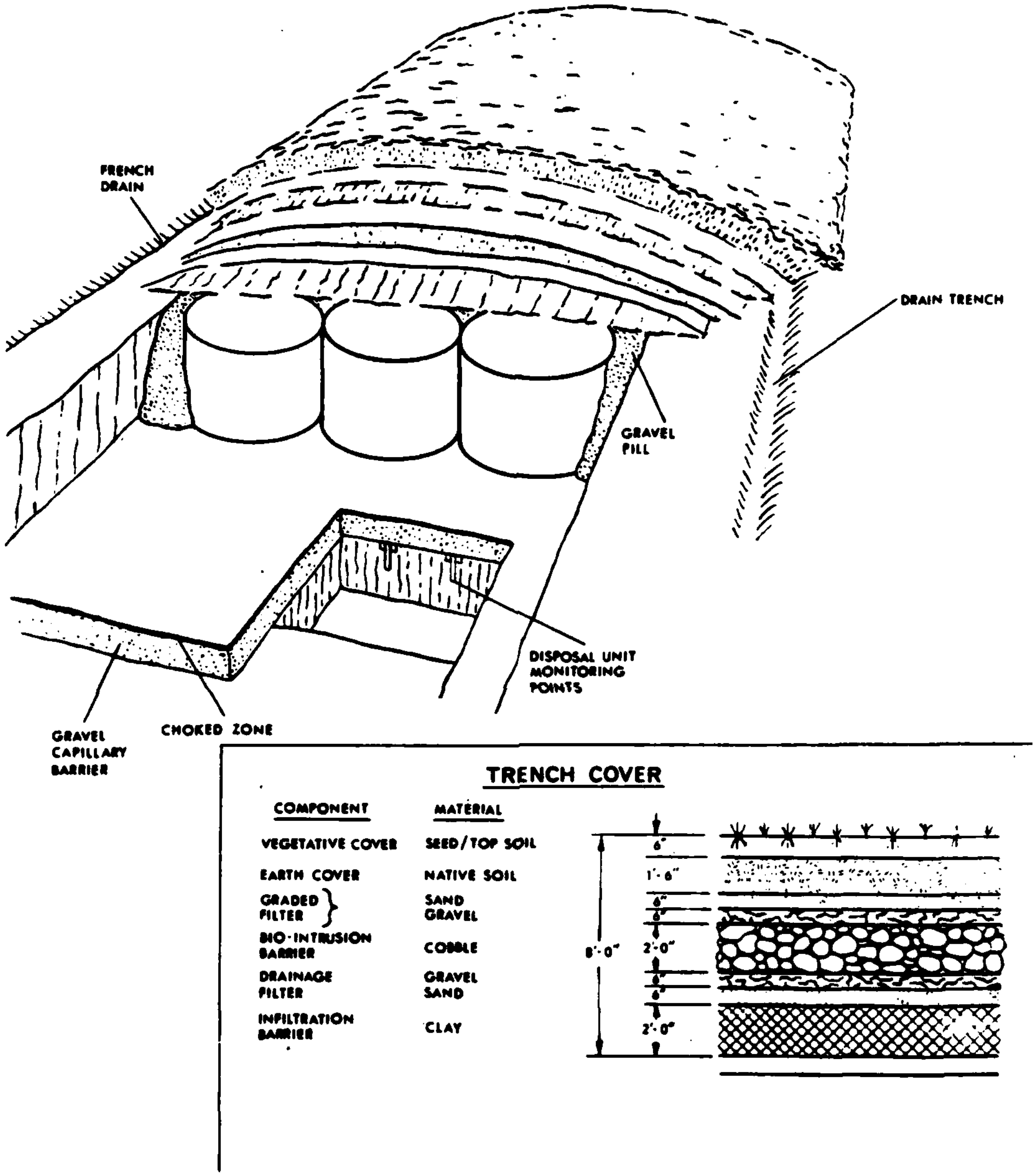

Figure A-7. Concrete Pipe Caissons

to allow for site drainage, and a site buffer zone of 200 feet, the complete site area will be 1300 feet by 4150 feet or 124 acres.

The pipe cassion design offers many of the same advantages as the concrete canister concept. Additional barriers are provided to ground water infiltration and to human or plant and animal intrusion. The grouting of the waste forms a concrete monolith which supports the trench cover. The caisson also resist seismic events, and will isolate the waste even if erosion or mass earth movement uncovers the disposal trench.

The standard pipe caissons are not suitable as interim storage containers since they lack a top and a bottom. Adding special tops and bottoms would be both difficult and costly, so the options of utilizing the pipe caissons as storage containers as was done with the concrete canister was not pursued.

h. Augered Caissons

The use of augered caissons, Figure A-8, for the disposal of defense low-level radioactive waste is currently being investigated at the Department of Energy's Nevada test site. A design similar to the DOE concept is described in this report. The site is cleared and graded, and the location of the 7-foot diameter auger holes are surveyed on 14-foot centers. Concrete forms which correspond to the auger hole diameter are placed at the auger hole locations, and a six-inch thick reinforced concrete pad is poured. The pad supports the weight of the auger and drains surface water away from the holes. For a yearly production of 1100 drums, 40 auger holes are required. The holes are arranged in four rows by 10 holes long. The concrete pad is 63 feet wide by

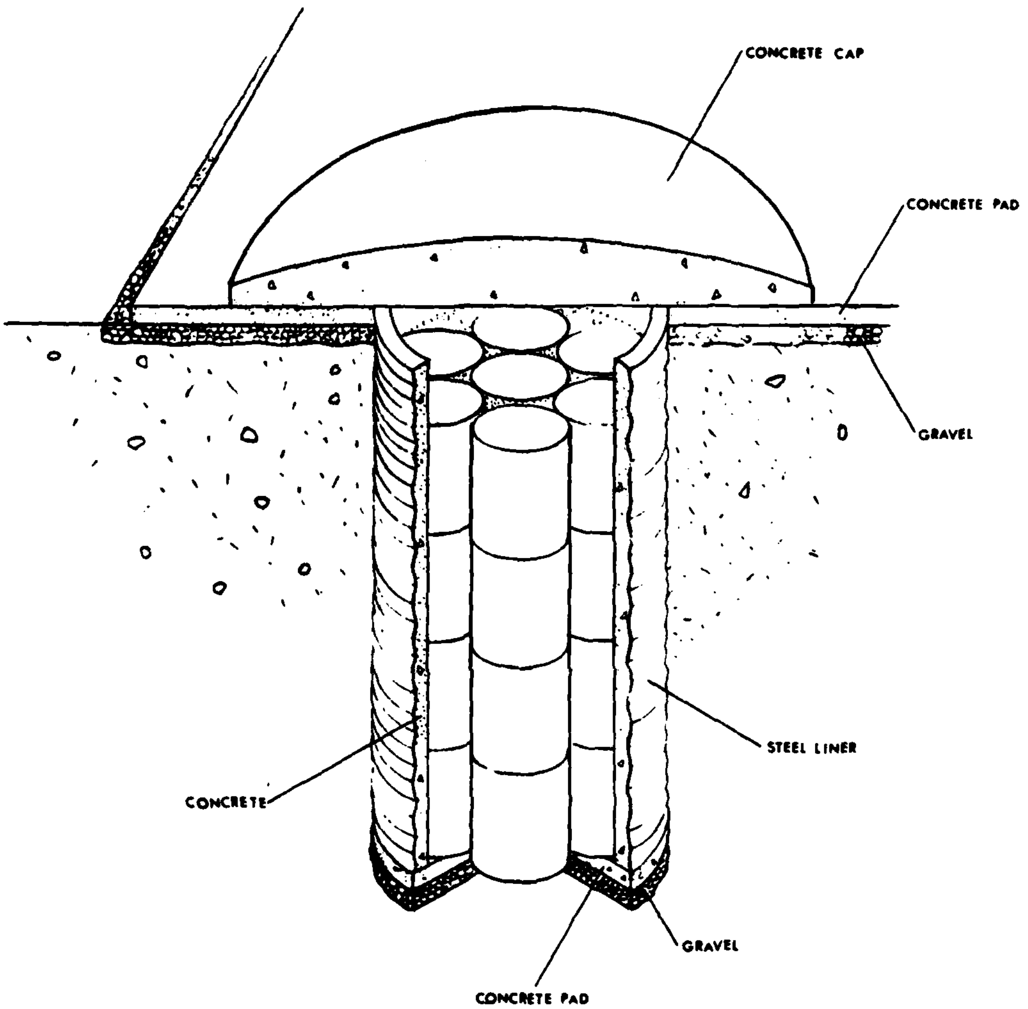

Figure A-8. Augered Caissons

154 feet long. The holes are augered to a depth of 15 feet, and the holes are lined with corrugated steel pipe to keep the walls from collapsing. The bottom of the hole is packed with gravel and concrete to form a base. The drums are lowered into the holes by a small mobile crane, and the void space between the drums are filled with grout. A concrete cap is then poured in place to seal the hole.

During the 20-year site operating period, 23 63-foot wide by 154-foot long concrete pads will be constructed. The pads will be arranged in two parallel rows with a 200-foot separation between rows. With a 20-foot separation between pads and a 200 site buffer zone, the complete site area will be 910 feet by 1420 feet or 30 acres.

The use of augered caissons requires a small site area, and lends itself to intermittent operation due to the short operating period for individual holes. The concrete cap is a barrier to inadvertent human or plant and animal intrusion. Filling the auger hole with grout isolates the waste from ground water and prevents the migration of radionuclides.

The concrete pad is subject to external events and will require regular maintenance throughout the site operating and institutional control periods. The auger holes and concrete pads are also susceptible to damage from seismic events.

3. PRELIMINARY COST ESTIMATES

Cost estimates were prepared for each of the on-site disposal concepts described in this report. The costs for construction of each disposal concept and for the site

preparation of each concept were estimated using general construction industry averages, and the averages used might not reflect the actual material, labor, and equipment rental costs encountered in the Florida panhandle area. Costs which are unique to siting, operating, and maintaining a low-level radioactive disposal facility were developed from several studies referenced at the end of this report. These costs are typical, and again they might not reflect the actual cost for Eglin Air Force Base operating its own disposal site. For the above reasons, the estimates are useful only for comparative purposes in evaluating the different disposal concepts and for selecting the concepts which Eglin Air Force Base wishes to develop further. The total cost and cost per unit volume for each disposal concept are summarized in Table A-2. Four main categories comprise the total cost, they are: first year direct cost, 20-year operating cost, site closure cost, and 100-year institutional cost. All costs are given in constant 1984 dollars.

a. First Year Direct Cost

The first year direct cost includes the material and labor necessary to site and construct the disposal facilities. The items which comprise the first year direct cost for each disposal concept are given in Table A-3. It is assumed in the estimate that the costs for site selection and environmental impact studies are the same for all the disposal options. Also, it is assumed that 1 year of project administration will be required for all the disposal concepts. Since the disposal units will not operate continuously throughout the operating years, the estimate assumes that all equipment used to construct and operate the various disposal concepts will be leased.

TABLE A-2
OVERALL DISPOSAL COSTS

($ X $1,000)

	First Year Direct Cost	Twenty Year Operating Cost	Site Closure Cost	Institutional Control Cost	Total Cost	Unit Cost Per Ft^2
Shallow Land Burial	$2,035	$5,204	$ 55	$4,086	$11,380	$59.50
Above Ground Vault	1,549	2,058	41	4,016	7,664	40.07
Above Ground Vault/ Cover	1,560	2,064	2,273	3,454	9,351	48.89
Below Ground Vault	2,067	5,399	55	4,086	11,607	60.69
Mounded Concrete Bunker	3,450	13,858	65	5,020	22,393	117.09
Concrete Canister	2,650	8,835	56	4,144	15,685	82.01
Concrete Canister Alt. 1	2,197	5,325	48	3,495	11,065	57.86
Concrete Canister Alt. 2	2,197	4,893	48	3,470	10,608	55.47
Pipe Caisson	2,293	6,682	55	4,117	13,147	68.74
Augered Caisson	1,943	4,591	48	3,851	10,433	54.55

TABLE A-3. FIRST YEAR DIRECT COST ITEMS

1.0 PREOPERATIONAL COSTS

- o Site Selection: $500,000
- o Environmental Impact Studies: $700,000

2.0 OPERATIONAL COSTS

2.1 Land Preparation

- o Site road with drainage ditches, $5.22/Ln.Ft.
- o Site perimeter fence. Galv. steel 6' high, 3 strand barbed wire, $8.00/Ln.Ft.
- o Site boundary wells, 10 wells per site, $1,240 each.
- o Site air monitors, 4 per site, $1,115 each.

2.2 Disposal Unit

- o Disposal unit construction
- o Unit drainage ditches, $4.00/Ln.Ft.
- o Surveyor, $60/hour, 8 hours/unit
- o Corner stones and monuments, $120/unit
- o Stand Pipes, $425/unit
- o Site monitoring wells, 1 well per 2 units, $620/unit

2.3 Administration

o	Project Leader	$ 55,000/year
o	Senior Engineer	35,000/year
o	Engineer	25,000/year
		$115,000 for one (1) year.

2.4 Engineering Design

- o Site and disposal unit design
- o Inspection
- o Contract Management

(Total Cost = 10% of item 2 plus 3% of item 3)

b. Twenty-Year Direct Operating Cost

The direct operating costs consist of labor, materials, and supplies required to operate and maintain the disposal site during the 20-year operational period. The items and yearly costs which comprise the 20-year direct operating cost are shown in Table A-4. The environmental monitoring plan which is the same for all the disposal options, and the cost in the twenty-first operating year is given in Table A-5.

TABLE A-4. TWENTY-YEAR DIRECT OPERATING COST ITEMS (20 YEAR OPERATING PERIOD - YEARLY COST)

OPERATION & MAINTENANCE

- o Site roads and drainage ditches, 10 percent of initial cost per year.
- o Site fences, 5 percent of initial cost per year.
- o Vegetation management, 10 percent of initial cost per year.
- o Equipment Replacement, 5 percent of initial cost per year.
- *o Concrete repair, 1 percent of initial cost per year.

DISPOSAL UNIT

- o Disposal unit construction
- o Seed, $1,020/acre
- o Unit drainage ditches, $4.00/Ln.Ft.
- o Surveyor, $60/hr, 8 hrs/unit
- o Corner stones and monuments, $120/unit
- o Stand pipes, $425/unit
- o Site monitoring wells, $620/unit

ADMINISTRATION

o	Project Leader	$ 55,000
o	Senior Engineer	$ 35,000
o	Engineer	$ 25,000
		$115,000 x Unit const. time (weeks)/52.

*Concrete repairs to above ground vault and auger caisson pad.

TABLE A-5. ENVIRONMENTAL MONITORING COSTS
(20-YEAR OPERATING PERIOD - YEARLY COST)

Sample	Number Locations	Type	Frequency	Unit Cost	Total Cost
External Gamma	20	Continuous	Quarterly (during operations)	$ 12	$ 480
Atmosphere	4	Continuous	Weekly (during operations)	165	7,920
			Monthly (9 mos.)	165	5,940
Soil & Vegetation	5	Grab	Quarterly	235	4,700
Boundary Wells	10	Grab	Semiannually	200	4,000
Disposal area wells	12*	Grab	Quarterly	200	9,600
Disposal unit sumps	23**	Grab	Monthly	200	5,600***
				TOTAL: 21st Year:	$38,240

* Two disposal area wells are built in the first year and one well per two years is built thereafter.

** One disposal unit sump is constructed per disposal unit.

*** Disposal unit sumps are surveyed on a monthly basis. Analysis would only take place if water was determined to be present in a sump. Assume that analysis takes place 10 percent of the time the sumps are surveyed.

Operation and maintenance costs include costs associated with routine operation and maintenance of site grounds, roads, and fences. Disposal unit construction takes place once a year during the facility operation. Construction operations include clearing away existing foliage, excavation of the disposal trench, installation of stand pipes, drainage ditches, disposal unit markers, and site monitoring wells. Project administration costs are assumed to occur only during the construction phase of each disposal unit.

c. Site Closure Costs

Closure activities involve the final preparation of the disposal site for the institutional control period. These include remedial work to the site perimeter drains, and an environmental monitoring program to insure that all radiation levels are at background. For consistency and comparative purposes, it is assumed that no remedial work to the disposal units themselves will be required. The items which comprise the site closure costs are shown in Table A-6.

Operation and maintenance costs include costs associated with routine operation and maintenance of site grounds, roads, and fences. Disposal unit construction takes place once a year during the facility operation. Construction operations include clearing away existing foliage, excavation of the disposal trench, installation of stand pipes, drainage ditches, disposal unit markers, and site monitoring wells. Project administration costs are assumed to occur only during the construction phase of each disposal unit.

d. Institutional Control Costs

In this estimate, the institutional control period is assumed to last for 100 years. For comparison purposes, it is assumed that all the disposal concepts remain in a stable condition throughout the institutional control period, and therefore only caretaking and environmental monitoring activities need to be performed. The items which comprise the institutional control costs on a yearly basis are shown in Table A-7.

TABLE A-6. SITE CLOSURE COSTS

FINAL GROUND PREPARATION

- o Perimeter drainage ditches remedial work, $1.80/Ln.Ft.
- o Vault cover (aboveground vault with earthen cover only)

*ADMINISTRATION

o	Project Leader	$ 55,000/year
o	Senior Engineer	$ 35,000/year
o	Engineer	$ 25,000/year
		$115,000/year one (1) year

*ENGINEERING DESIGN

- o Disposal vault cover design
- o Project management
- o Inspection

ENVIRONMENTAL MONITORING

Sample	Number Locations	Type	Frequency	Unit Cost	Total Cost
External Gamma	4	Continuous	Quarterly	$ 12	$ 192
Atmosphere	4	Continuous	Monthly	165	7,920
Soil & Vegetation	5	Grab	Semiannually	235	2,350
Boundary Wells	10	Grab	Semiannually	200	4,000
Disposal Site Wells	12	Grab	Quarterly	200	9,600
Disposal unit sumps	23	Grab 10%	Quarterly	200	1,840
				CLOSURE YEAR TOTAL:	$25,902

*Install earthen cover over aboveground vault.

TABLE A-7. INSTITUTIONAL CONTROL COST (100 YEAR CONTROL - YEARLY COSTS)

SITE MAINTENANCE:

- o Site roads and drainage ditches, 10 percent of direct cost per year.
- o Site fences, 5 percent of direct cost per year.
- o Vegetation Management, 10 percent of direct cost per year.
- o Equipment replacement, 5 percent of direct cost per year.
- o *Concrete repair, 1 percent of direct cost per year.

SITE CARETAKER:

- o Caretaker, $20,000/year.

ENVIRONMENTAL MONITORING

Sample	Number Locations	Type	Frequency	Unit Cost	Total Cost
External Gamma	4	Continuous	Quarterly	$ 12	$ 192
Atmosphere	1	Continuous	Monthly	165	1,980
Soil & Vegetation	3	Grab	Annually	235	705
Boundary Wells	5	Grab	Semiannually	200	2,000
Disposal Site Wells	6	Grab	Semiannually	200	2,400
Disposal unit sumps	23	Grab (10%)	Annually	200	460
				YEARLY TOTAL:	$ 7,737

*Concrete repairs to aboveground vault and auger caisson pad.

4.0 BIBLIOGRAPHY

U.S. Nuclear Regulatory Commission, Draft Environmental Impact Statement on 10CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste," NUREG-0782, September 1981.

U.S. Nuclear Regulatory Commission, Final Environmental Impact Statement on 10CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Wastes," NUREG-0945, November 1982.

Bennett, R.D., et.al., Alternative Methods for Disposal of Low-Level Radioactive Wastes, NUREG/CR-3774, April 1984.

Murphy, E.S., G.M. Holter, Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground, NUREG/CR-0570, June 1980.

Macbeth, P.J., et.al., Evaluation of Alternative Methods for the Disposal of Low-Level Radioactive Wastes, NUREG/CR-0680, July 1979.

Johnson, T.M., et.al., "An Investigation of Layered Covers to Limit Infiltration at Waste Disposal Sites," in Proceedings of the Symposium on Low-Level Waste Disposal, NUREG/CR-0028, March 1983.

U.S. Department of Energy, Economics of a Low-Level Radioactive Waste Management Facility for the Rocky Mountain Region, DOE/ID/12371-6, September 1983.

Hittman Nuclear & Development Corporation, Decommissioning Plan for the Maxey Flats Disposal Site, Identification of Alternatives, WTSD-TME-015, October 1983.

Hittman Nuclear & Development Corporation, Decommissioning Plan for the Maxey Flats Disposal Site, Evaluation of Alternatives, WTSD-TME-019, December 1983.

U.S. Department of Energy, Greater Confinement Disposal Test at the Nevada Test Site, DOE/NV/00410-79, June 1983.

Rogers, V.C., et.al., A Handbook for Low-Level Radioactive Waste Disposal Facilities, Electric Power Research Institute, EPRI NP-2488-LD, September 1982.

Building Construction Cost Data 1983, Robert Snow Means Company, 41st Edition, 1982.

Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, American National Standard Institute, ANSI A58.1-1972.

Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants, American National Standards Institute, ANSI N18.2-1973.

APPENDIX B

ASSUMPTIONS USED IN ESTIMATING COST OF PROCESSING, PACKAGING AND DISPOSAL

1. LABOR RATES (Burdened)

a.	Forklift Operator	$ 26 per hour
b.	Common Laborers	$ 21 per hour
c.	Mixer Operator	$ 26 per hour
d.	Foreman	$ 45 per hour

2. EQUIPMENT RENTAL

a.	Cement silo and mixer	$ 3,445 per month
b.	Compactor	$ 37 per drum

3. EQUIPMENT PURCHASES

a.	Electrical Heaters	$44,000
b.	Rotary Dryer & Filter	$70,000

4. MATERIALS

a.	Cement	$ 0.05 per pound
b.	Lime	$ 0.08 per pound
c.	55 gallon drums	$ 25 each
d.	Overpacks	$ 50 each

5. TRANSPORTATION

a.	Eglin to Beatty, NV	$ 4,809 per trip

6. BURIAL COST

a.	Basic charge	$ 17.85 per CF
b.	Inspection charges	
	(1) Initial fee	$ 1,000
	1 - 5,000 CF	$ 3.50 per CF
	5,000 - 10,000 CF	$ 3.00 per CF

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APPENDIX C

METHOD FOR ESTIMATING THE QUANTITY OF URANIUM IN MIXTURES OF SAND AND URANIUM FRAGMENTS

NOMENCLATURE

V_c = Internal Volume of Container (CF)

V_v = Void volume in container including unfilled and interstitial voids (CF)

V_t = Total volume of solids (CF)

V_u = Volume of uranium (CF)

V_s = Volume sand (CF)

V_i = Volume test penetrators (iron) (CF)

D_u = Particle density of uranium (1,168 lbs/CF)

D_s = Particle density of sand (165 lbs/CF)

D_i = Particle density of iron (491 lbs/CF)

W_g = Gross weight of filled container

W_c = Weight of container

W_t = Weight of contents (i.e., total weight of solids)

N_u = Number of uranium penetrators in firing cycle

$$N_i = \text{Number of test penetrators in firing cycle}$$

MIXTURES OF SAND AND URANIUM FRAGMENTS

$$V_t = V_c - V_v$$

$$V_t = V_s - V_u$$

$$W_t = W_g - W_c$$

$$W_t = 165\ V_s + 1,168\ V_u$$

$$165\ V_t = 165\ V_s + 165\ V_u$$

Subtracting

$$W_t - 165\ V_t = 1,003\ V_u$$

$$V_u = \frac{(W_t - 165\ V_t)}{1003}$$

$$W_u = \frac{1168}{1003}\ (W_t - 165\ V_t)$$

$$W_u = 1.1645\ W_t - 192.14\ V_t$$

MIXTURE OF SAND, URANIUM AND IRON FRAGMENTS

$$V_t = V_s + V_u + V_i$$

$$V_i = \frac{N_i}{N_u} \times V_u$$

$$V_t = V_s + V_u + V_u \left(\frac{N_i}{N_u} \right)$$

$$W_t = 165\ V_s + 1168\ V_u + 491\ V_u \left(\frac{N_i}{N_u} \right)$$

$$165\ V_t = 165\ V_s + 165\ V_u + 165\ V_u \left(\frac{N_i}{N_u} \right)$$

Subtracting

$$W_t - 165\ V_t = 1003\ V_u + 326\ V_u \left(\frac{N_i}{N_u} \right)$$

$$= V_u \left[(1003 + 326 \left(\frac{N_i}{N_u} \right) \right]$$

$$V_u = \frac{W_t - 165\ V_t}{1003 + 326 \left(\frac{N_i}{N_u} \right)}$$

$$W_u = 1168 \left[\frac{W_t - 165\ V_t}{1003 + 326 \left(\frac{N_i}{N_u} \right)} \right]$$

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APPENDIX D

EGLIN AIR FORCE BASE
DEPLETED URANIUM WASTE DISPOSAL CONTINGENCY PLAN
(PROPOSED)

1. INTRODUCTION

The Eglin AFB generates low-level radioactive waste in the testing of armor penetrator munitions. Depleted uranium armor penetrators are fired into a sand target butt as part of acceptance testing of new munitions and quality assurance testing of munitions from the war reserve. Approximately 50,000 penetrators are fired each year. After about 25,000 penetrators are fired into the target, the core of the target is removed. The sand is sieved to remove the penetrator fragments. The penetrator fragments and associated sand are placed into 16-gallon drums. The sand passing through the sieve is returned to the target butt. After approximately 100,000 penetrators (i.e., 3 to 4 firing cycles) have been fired into the butt, the entire butt is removed. The sand is sieved to remove penetrator fragments, and the residual sand is placed into 55-gallon drums. Approximately 1100 55-gallon drums of contaminated sand are produced by each sand change.

The target butt is partially enclosed in a building with controlled ventilation. Air from the building is exhausted through H.E.P.A. filters which collect any airborne contamination. The H.E.P.A. filters are compacted into 55-gallon drums. Approximately 10 drums of H.E.P.A. filter waste is generated in each firing cycle. Some tests are conducted in which depleted uranium penetrators are fired at armor plate

or concrete blocks, causing localized contamination. The plates and blocks are then decontaminated, which produces a small quantity of depleted uranium waste.

2. PROJECTED WASTE VOLUME

Based on testing 50,000 penetrators annually during two firing cycles, the estimated quantities of waste requiring off-site disposal are as follows:

Fiscal Years	Total Volume (CF)	Penetrator Fragments (No. 16-Gal)	Contaminated Sand (No. 55 Gal)	H.E.P.A. Filters (No. 55 Gal)	Misc. Waste (No. 55 Gal)
1986	8700	100*	1100	20	5
1987	360	67	-	20	5
1988	8700	100*	1100	20	5
1989	360	67	-	20	5
1990	8700	100*	1100	20	5

*Includes additional drums of fragments sieved during target butt change.

3. WASTE CHARACTERISTICS AND EXPOSURE DATA

a. Penetrator Fragments

The penetrator fragments will be packaged in 16-gallon steel drums (17H). Each drum will contain about 315 pounds of depleted uranium and about 185 pounds of dry sand. The total weight of the drums will be approximately 515 pounds each. The activity per drum will be approximately 45 millicuries, and the specific activity will be about 200 nanocuries per gram. The external radiation will be less than 3 mRem per hour.

b. Contaminated Sand

The drums of contaminated sand will generally contain 1 to 5 weight percent depleted uranium with some drums containing as much as 10 weight percent. The drums weigh 860 to 950 pounds each. The specific activity of the drums containing 10 weight percent depleted uranium is about 30 nanocuries per gram, and the total activity is about 12 millicuries per drum. The external radiation will be less than 1 mRem per hour.

c. H.E.P.A. Filters

The drums containing H.E.P.A. filters will weigh about 250 pounds. The contamination consists primarily of small particles of uranium oxide embedded in the filters. The specific activity is less than 1 nanocurie per gram, and the external radiation is slightly above background.

d. Miscellaneous Waste

The waste consists of contaminated clothing and materials packaged in 55-gallon steel drums. It also includes residue from decontaminated target materials either solidified or absorbed. The specific activity is less than 1 millicurie per gram, and the external radiation levels are slightly above background.

4. ON-SITE STORAGE

There is no covered storage space for radioactive materials at the test site at Eglin AFB. Drums containing depleted uranium waste are stored outside in fenced storage areas

pending shipment. Shipments must be made within a few weeks after packaging to minimize deterioration of packaging.

5. CHARACTERIZATION OF WASTE

The wastes have been characterized and do not contain any hazardous wastes as defined in 40 CFR 261.

6. COMPLIANCE WITH DOT SHIPPING REGULATIONS

a. Penetrator Fragments

The penetrator fragments will be packaged with dry sand in 18-gallon drums. The fragments and sand will have been dried at temperatures exceeding 300°F, and all potentially pyrophoric uranium will be converted to oxide and rendered non-pyrophoric. The material will be shipped as Low Specific Activity Radioactive Material, LSA, in drums qualified as strong, tight industrial containers. The drums will be labelled "Low Specific Activity Radioactive Material Uranium Metal and Uranium Oxide - Non-Pyrophoric."

b. Contaminated Sand

The contaminated sand containing 1 to 20 percent depleted uranium will be packaged into 55-gallon steel drums. The sand will have been dried at temperatures exceeding 300°F, and all potentially phyrophoic uranium will be converted to oxide and rendered non-pyrophoric. The material will be shipped as Low Specific Activity Radioactive Material in 17H drums. The drums will be classified as strong tight industrial containers because the weight will exceed the limits for classification of these drums as Type A containers.

The drums will be labelled as "Low Specific Activity Radioactive Material."

c. H.E.P.A. Filters

The H.E.P.A. filters will be compacted into 55-gallon steel drums. The drums will be classified as strong tight industrial containers, and the packages will be labelled, "Low Specific Activity Radioactive Material."

d. Miscellaneous Waste

The miscellaneous wastes will be packaged in 17H 55-gallon drums. Homogeneous waste classifiable as low specific activity radioactive material will be shipped and labelled as "Low Specific Activity Radioactive Material." Heterogeneous materials not classifiable as LSA will be shipped and labelled as Type A shipments.

7. PACKAGING AT MAXIMUM DENSITY

Packages containing penetrator fragments and sand and sand contaminated with depleted uranium will be filled to greater than 90 percent of container volume. H.E.P.A. filters will be compacted into drums using a hydraulic compactor. To the extent possible, miscellaneous waste will be compacted into drums. Where compaction is not possible, drums will be hand packed to achieve maximum packaging density.

8. COMPLIANCE WITH BURIAL SITE REQUIREMENTS

The waste will have been rendered non-pyrophoric and will be shown to be non-reactive when immersed in water. All

waste will be packaged in metal containers. Any special requirements of the designated Department of Energy disposal site will be incorporated into the packaging procedures.

9. BURIAL COMPLIANCE WORK SHEET

Attachment A contains a completed, "Burial Compliance Check Sheet for Radioactive Material."

10. SOLID WASTE

Attachment B contains completed, "Solid Waste Burial Record - Non Transuranic" forms for the four waste types.

11. STRUCTURAL ANALYSIS AND HANDLING PROCEDURES

No special containers will be used and no special handling procedures are required.

12. IMPLEMENTATION PLAN

a. The responsible individual designated in the Eglin AFB permit, hereinafter referenced as the permit designee, will be responsible for the implementation of the plan for the disposal of radioactive waste at D.O.E. disposal sites.

b. The permit designee will be responsible for resolution of DOD and DOE comments on this implementation plan and for assuring that a current and approved implementation plan is in effect at all times.

c. The permit designee will initiate correspondence requesting the DOE to identify the DOE disposal

site designated to receive waste from Eglin AFB in the event commercial disposal sites are not available.

d. Following the designation of the DOE disposal site, the permit designee will establish contact with key personnel at the designated site and will obtain the guidelines for the acceptance of waste at the designated site.

e. The permit designee will prepare procedures for the processing, packaging and transportation of waste to comply with the DOE acceptance criteria and applicable regulations.

f. The permit designee will obtain the concurrence of the designated DOE site on the processing, packaging and transportation procedures and will obtain the approval of other governmental agencies as required.

g. The permit designee will maintain contact with the commercial burial site, cognizant state authorities and regional compact organizations and will take those actions necessary to obtain space allocations and to comply with burial site requirements.

h. If conditions are encountered whereby the waste generated by Eglin AFB will not be accepted at commercial burial sites, the permit designee will immediately notify the cognizant individuals within DOD and DOE of the circumstances leading to non-acceptance of waste. Oral notifications will be followed by formal correspondence requesting implementation of the contingency plan and the allocation of space at the designated DOE facility.

i. The permit designee will initiate action to have an interagency agreement executed to provide funds to the designated DOE site for the handling and disposal of wastes from Eglin AFB.

j. The permit designee will initate actions to reduce the volume of waste generated and to provide temporary storage to the maximum possible extent until commercial burial space becomes available.

k. The permit designee will orally report to cognizant individuals in DOD and DOE any incidents or accidents that occur in connection with the disposal of waste at DOE facilities and will provide written reports covering such incidents and accidents.

l. The permit designee will maintain contact with commercial disposal sites, responsible state authorities and regional compact organizations and will solicit the continuance of acceptance of waste from Eglin AFB. The permit designee will provide monthly reports on the status of these negotiations.

m. The permit designee will notify the cognizant individuals within DOD and DOE when commercial burial space will become available.

n. The permit designee will take those actions necessary to terminate the use of DOE disposal facilities in an orderly manner and to resume the use of commercial disposal sites.

13. POINTS OF CONTACT

The permit designee will prepare and maintain a list of cognizant individuals within DOD and DOE, complete with office and home addresses and telephone numbers.

ATTACHMENT A

BURIAL COMPLIANCE CHECKSHEET
FOR RADIOACTIVE SOLID WASTE MATERIAL

Rockwell Storage & Disposal Approval Number	Date	Rockwell Solid Waste Processing & Disposal Unit Approval Signature

Waste Generator: Armament Division, Eglin AFB, Florida

Waste Title: Depleted Uranium Waste

Storage/Disposal Container: 18-gallon and 55-gallon Steel Drums

Reference: RHO-MA-222, Rev.2 (Unclassified), July 1984, D.P.Belgrair, "Hanford Radioactive Solid Waste Packaging, Storage and Disposal Requirements"

Waste Type:
[ ] Classified
[x] Non-Transuranic
[ ] Transuranic WIPP Certified
[ ] Transuranic WIPP Un-Certified

Disposal Type:
[x] Scheduled
[ ] Retrievable Storage
[ ] Non-Scheduled
[x] Contact Handled
[ ] One-Time Only
[ ] Remote Handled
[ ] Direct Burial

Transport Criteria:
[x] U.S.Department of Transportation
[ ] Waste Generator
[ ] Rockwell Transport Approval Number: ____________

Transport Category:
[x] Low Specific Activity
[ ] Limited Quantity
[x] Type A
[ ] Type B
[ ] Highway Route Controlled Quantity

ATTACHMENT A

A. WASTE DESCRIPTION

Rockwell Storage &
Disposal Approval
Number

1. Waste Contents Included:

Yes	No		Yes	No	
[x]	[ ]	Miscellaneous Solid Waste	[ ]	[x]	Tritium
[ ]	[x]	Animal Carcasses	[ ]	[x]	Alkali Metals
[ ]	[x]	Unabsorbed Liquid Organics	[ ]	[x]	Asbestos
[ ]	[x]	Ion Exchange Columns	[ ]	[x]	Lead Shielding
[ ]	[x]	DOT Class B Poison: ______	[ ]	[x]	Gas Generating Potential
[ ]	[x]	Heat Generating Potential (Greater than 0.1 watts/cf)	[ ]	[x]	Hazardous Material Co-contamination
[x]	[ ]	Other: Uranium metal rendered non-pyrophoric			

Note: The following are prohibited: Free inorganic liquids, incompatible materials, pyrophorics, explosives, unreacted alkali metals, and unvented gas cylinders.

2. Physical Description of Waste:
   a. Depleted uranium fragments and sand in 18-gallon steel drums
   b. Sand contaminated with depleted uranium in 55-gallon steel drums
   c. HEPA filters containing uranium oxide in 55-gallon steel drums
   d. Miscellaneous waste consisting of depleted uranium-contaminated clothing, material and decontamination waste in 55-gallon drums

3. Radionuclide Activity Description

   Non-Transuranic:
   a. Depleted uranium fragments @ 200 nanocuries/gram and 45 millicuries/drum
   b. Contaminated sand @ 30 nanocuries/gram and 12 millicuries/drum
   c. HEPA filters @ less than 1 nanocurie/gram
   d. Miscellaneous waste @ less than 1 nanocurie/gram

   Transuranic:

   Not applicable

4. Hazardous Material Co-contaminant Description:

   None

5. Maximum Allowable Fissile Quantity:

   Less than 2 lbs/drum, Uranium 235

6. Void Space Filler Material:

   Dry sand

ATTACHMENT A

B. WASTE PACKAGING SYSTEM

Rockwell Storage & Disposal Approval Number ______________

1. Container Name: 18-gallon Steel Drum
55-gallon Steel Drum

2 Drawing or Specification Number: 17H

3. External Dimensions: 18-gallon Steel Drum: Diam. 14.875 in; Height 26.75 in
55-gallon Steel Drum: Diam. 23.84 in; Height 34.81 in

4. Disposal Volume: 18-gallon Steel Drum: 2.5 cf
55-gallon Steel Drum: 7.5 cf

5. Maximum Gross Weight: 18-gallon Steel Drum: 525 lbs
55-gallon Steel Drum: 975 lbs

6. General Description:

18-gallon drums containing 60 weight percent depleted uranium fragments in dried sand
55-gallon drums containing 1 to 20 weight percent uranium and uranium oxide in dried sand
55-gallon drums containing HEPA filters and miscellaneous waste

7. Required Internal Packaging:

Heat drying to dry sand and oxide potentially pyrophoric materials

8. Closure Mechanism:

Bolted ring

9. Maximum Allowable Radiation Levels: ______________(Contact)
______________(Other)

10. Maximum Allowable Surface Contamination: ______________

11. Required Labels:

18-gallon Drums: Low Specific Activity Radioactive Material
Uranium Metal - Non-Pyrophoric

55-gallon Drums: Low Specific Activity Radioactive Material

ATTACHMENT A

B. WASTE PACKAGING SYSTEM (Continued)

Rockwell Storage & Disposal Approval Number

12. Returnable Transport Overpacks:

None

Note: The Waste Generator must send a current Certificate of Compliance (COC) and Safety Analysis for Packaging (SARP) for each type of Returnable Transport Overpack to Rockwell prior to the initial shipment and each time these documents are revised.

C. OTHER REQUIREMENTS

1. Administrative Controls:

Eglin Air Force Base, Depleted Uranium Waste Disposal Contingency Plan

2. Rockwell Storage/Disposal Instructions:

ATTACHMENT B

Rockwell Hanford Operations | **SOLID WASTE BURIAL RECORD – NON-TRANSURANIC**

USE BLACK BALL POINT PEN OR TYPE

SWBDT RECORD NO.:

DISPOSAL SITE This portion of form to be completed by Rockwell Representative at Disposal site.

Area	Burial Ground No.	Trench No.

Caisson No.

Beginning Coordinates N ______ W ______

Ending Coordinates N ______ W ______

Remarks

Signature - Acceptance | Date

Accepted Per SOP No.

Signature - Burial | Date

ORIGINATOR

End Function - Shipment No. | DOE Authorization No. (RRM)

Company: Eglin Air Force Base

Building: Armament Laboratory | Area

Address/Phone:
AD/TFRL
Eglin AFB, Florida 32542
(904) 882-4481

I certify that no capital property is included in this burial unless documented by a Property Disposal Request, and described below, and that the contents meet RHO-MA-222 requirements and are packaged in Rockwell approved containers per RHO-MA-222.

Signature ______ Date ______

I certify that the waste package description below is complete based on an internally approved inspection system and that the waste package conforms to RHO-MA-222 and the approval authorization.

Signature (Independent Reviewer) ______ Date ______

Method of Inspection/File No.:

PHYSICAL DESCRIPTION

Material Contents

Depleted uranium fragments in dried sand packaged in 18-gallon steel drums. Drums contain approximately 315 pounds of depleted uranium and about 185 pounds sand. Total activity about 45 millicuries with specific activity about 200 nanocuries per gram.

Toxic/Hazardous Materials: None

Property Disposal Request No.	Vol. % Combustible	Vol. % Noncombustible
	0	100

Container — All Containers Must be Approved by Rockwell Hanford Operations

Approval Number(s)	Quantity		Hanford Standard Fiberboard (18" x 18" x 24")
		x 18 Gallon Drum	

Length	Width	Height	Diameter	Material of Construction
		26.75 in.	14.875 in.	Carbon Steel

General Description: Standard steel drum with bolted ring gasketed closure

TOTAL VOLUME (FT^3) 2.5 | Gross Weight 525 max. ☒ Pounds ☐ Kilograms | Nuclear Transaction No.

ACTIVITY DESCRIPTION

General Activity Description (E.G. long-lived isotopes such as Pu, Co, Sr, Cs; mixed fission products, activation products)

Depleted Uranium containing more than 99.5 percent U-238 and less than 0.5 percent U-235

Plutonium	TRU other than Pu
0 Grams	0 Grams

Fissile Content	Uranium	Activity (TRU/U - not included)
715 Grams	143,000 Grams Less than 0.5% Enrichment	Total Shipment ______ Curies 4.5×10^{-5}

Dose Rate - Package ______ mr/hr at ______ ☐ Surface ☐ Inches ☐ Feet

Dose Rate - Shipment ______ mr/hr at ______ ☐ Surface ☐ Inches ☐ Feet

DISTRIBUTION: BY SHIPPER White, Yellow, Pink } With Shipment; Goldenrod - Retain. BY ROCKWELL White - SWBDT, 2750-E; Yellow - Nuclear Materials, 2704-Z; Pink - Return to Shipper

54-3000-581 (R-4-82)

ATTACHMENT B

Rockwell Hanford Operations	SOLID WASTE BURIAL RECORD — NON-TRANSURANIC
USE BLACK BALL POINT PEN OR TYPE	SWBDT RECORD NO.:

DISPOSAL SITE This portion of form to be completed by Rockwell Representative at Disposal site.

Area	Burial Ground No.	Trench No.
Caisson No.	Beginning Coordinates N ______ W ______	
	Ending Coordinates N ______ W ______	

Remarks

Signature - Acceptance	Date
Accepted Per SOP No.	
Signature - Burial	Date

ORIGINATOR

End Function - Shipment No.	DOE Authorization No. (RRM)
Company: Eglin Air Force Base	
Building: Armament Laboratory	Area

Address/Phone
AD/TFRL
Eglin AFB, Florida 32542
(904) 882-4481

I certify that no capital property is included in this burial unless documented by a Property Disposal Request, and described below, and that the contents meet RHO-MA-222 requirements and are packaged in Rockwell approved containers per RHO-MA-222.

Signature ______ Date ______

I certify that the waste package description below is complete based on an internally approved inspection system and that the waste package conforms to RHO-MA-222 and the approval authorization.

Signature (Independent Reviewer) ______ Date ______

Method of Inspection/File No.:

PHYSICAL DESCRIPTION

Material Contents

55-gallon drums containing either: (1) Sand contaminated with depleted uranium metal and oxide; (2) HEPA filters contaminated with uranium oxide; or (3) miscellaneous waste consisting of contaminated clothing and material and decontamination waste.

Toxic/Hazardous Materials: None

Property Disposal Request No.	Vol. % Combustible	Vol. % Noncombustible
	0	100

Container	Approval Number(s)	Quantity	55 Gallon Drum	Hanford Standard Fiberboard (18" x 18" x 24")
All Containers Must be Approved by Rockwell Hanford Operations			x	
	Length	Width	Height: 34.81 in.	Diameter: 23.84 in.	Material of Construction: Carbon Steel
	General Description: Standard steel drum with bolted ring gasketed closure				

TOTAL VOLUME (FT^3) 7.5 — Gross Weight 975 max. ☒ Pounds ☐ Kilograms — Nuclear Transaction No.

ACTIVITY DESCRIPTION

General Activity Description (E.G. long-lived isotopes such as Pu, Co, Sr, Cs; mixed fission products, activation products.

Depleted uranium containing more than 99.5 percent U-238 and less than 0.5 percent U-235.

Plutonium	TRU other than Pu	
______ Grams	______ Grams	

Fissile Content	Uranium	Activity (TRU/U - not included)
420 Grams	84,000 Grams Less than 0.5 Enrichment	Total Shipment ______ Curies Max/Container 1.2×10^{-5}

Dose Rate - Package	Dose Rate - Shipment
______ mr/hr at ______ ☐ Surface ☐ Inches ☐ Feet	______ mr/hr at ______ ☐ Surface ☐ Inches ☐ Feet

DISTRIBUTION: BY SHIPPER: White, Yellow, Pink — With Shipment; Goldenrod - Retain. BY ROCKWELL: White - SWBDT, 2750-E; Yellow - Nuclear Materials, 2704-Z; Pink - Return to Shipper

54-3000-581 (R-4-82)

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APPENDIX E

IMPACT ON THE SURFACE AND GROUNDWATER
ENVIRONMENTS OF A DEPLETED URANIUM
WASTE DISPOSAL FACILITY AT EGLIN AFB, FLORIDA

1. INTRODUCTION

This document uses available background information to develop an impact assessment for the waterborne pathways associated with a depleted uranium disposal facility at Eglin A.F.B. Airborne and other non-aqueous pathways have been dealt with in operationally oriented portions of the report on alternative methods of disposal. This document is prepared in support of an application for the amendment of the present license to allow on-site disposal under 10 CFR 20.302.

Assessment of the impact upon the water systems around the site requires a sequential examination of:

Uranium Toxicology

Physiography, Climate Hydrogeologic Setting, Hydrology and Hydrogeology of the Potential Site

Equilibrium Geochemistry and Uranium Speciation

Release Scenario/Source Term

Pathways Analysis and

Dose Assessment

The site waste application level is based on the highest available disposal option (Option 4) under 10 CFR 20.302, and this assessment is made on that basis.

2. URANIUM TOXICOLOGY

Uranium is toxic to humans in two ways. First, it is a nephrotoxin (kidney toxin) and second, it is a low specific activity alpha-emitting radionuclide which once in the bloodstream is partially retained in specific body areas or organs.

a. Chemical Toxicity

Uranyl (UO_2^{+2}) compounds and uranyl carbonate complexes are very soluble, and these species of uranium are very mobile at the pH found in bodily fluids (Reference E-1). Ninety-five percent of the uranium ultimately retained in the body is deposited in the bone. It is primarily excreted through the kidneys and thereby damages the proximal tubule, a critical part of the kidney. The earliest symptoms of this damage are an increase in urinary catalase and albuminuria observed in both animals and humans. Experiments on volunteers and terminally ill patients utilized single injections of between 20-100 micrograms per kilogram body weight $UO_2(NO_3)_2$ to induce these symptoms (Reference E-2). Thus, a 180-pound person would require a concentrated intra-venous dose of 6-7 milligrams of $UO_2(NO_3)_2$ before the kidneys would be affected. Within 24 hours, 60 percent of such a dose is excreted in the urine; 25 percent may ultimately be fixed in bone (Reference E-3).

The principal concern with uranium in water pathways would be oral ingestion and the associated potential chemical toxicity. The fraction of uranium going from the gastro-intestinal tract into the blood is 0.01 (Reference E-3). Consequently, a dose of from 600 to 700 milligrams would be required to indicate renal problems in the hypothetical 180-pound person. This chemical dose could come in

the form of 600 to 700 ppm uranium in a liter of ingested water.

The likelihood of this occurrence at the Eglin site will be discussed in the Release Scenario Section.

b. Radiotoxicity

When uranium is retained in the bone or other critical organ, the uranium atoms emit alpha particles which cause damage within a cell on the genetic and biochemical level. Retained-in-bone uranium can expose cells to these conditions for a relatively long time.

The International Commission on Radiological Protection (ICRP) has dose commitment formulae that can be used to compute doses to a person from certain aqueous concentrations ingested by that person. The dose section of this document provides a series of dose calculations based on ICRP formulae for expected aqueous uranium concentrations. A concentration of between 0.1 and 1 ppm would provide a 10 rem (equivalent to natural background) 50-year whole body equivalent exposure. The U.S. Environmental Protection Agency (EPA) standards limit the exposure to 1.25 rem for the same exposure period. This would require a human water consumption exposure to aqueous uranium concentrations between 10 and 100 ppb. The Nuclear Regulatory Commission (NRC) standard for soluble U-238 (not depleted uranium) taken from 10CFR20, Appendix B, Table II is 120 ppb.

In general, lower aqueous uranium concentrations ranging from 10 ppb to 1 ppm in water for human consumption will provide radiological doses that begin first to exceed EPA and then NRC Standards and finally exceed average natural background radiation exposure levels by a factor of two. The

precise threshold where this dosage assumes health-related significance in long term exposure periods is not clear.

3. PHYSIOGRAPHY, CLIMATE, HYDROLOGY, HYDROGEOLOGIC SETTING AND HYDROGEOLOGY OF THE PROPOSED SITE

The two candidate sites generally located on Figure E-1, taken from the report entitled "Soils and Groundwater Conditions at Two Borrow Pits, Eglin Air Force Base" (Reference 4), were considered early on as possible disposal sites; however, TAC-62 has been ruled out because it is an active test range and because waste would require approximately a haul of 15 miles from its present storage area (near TAC-64) to a TAC-62 disposal site. Therefore this document will focus on a potential site at TAC-64.

a. Physiography

TAC 64 is located within the the Spencer Flats 7-1/2' USGS Quadrangle in northwestern Florida about 12 miles NNE of Niceville, FL. This general location is depicted in Figure E-1. The specific location of TAC-64 is shown on Figure E-2. Drainage basin boundaries for Ramer Creek, Bull Creek and the southern portion of Titi Creek's basin in the reach connecting Ramer and Bull Creeks are also delineated on Figures E-2 and E-3. Typically 80 percent of the Basin's areas are uplands and 20 percent are valley slopes.

b. Climate

Mean daily temperatures range from 21.1°C to 26.7°C in the summer and they range from 10.0°C to 21.1°C in the winter. The mean monthly precipitation ranges from 3.2 inches to 7.2 inches. The annual average precipitation is 61 inches (Reference 5).

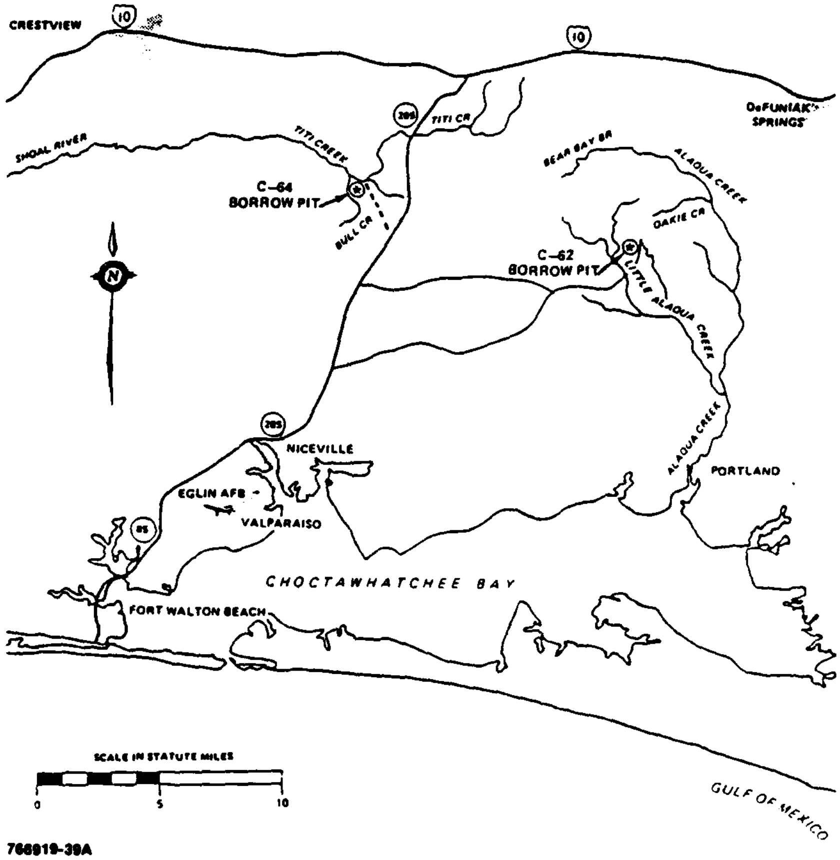


Figure E-1. TAC 64 Location Map

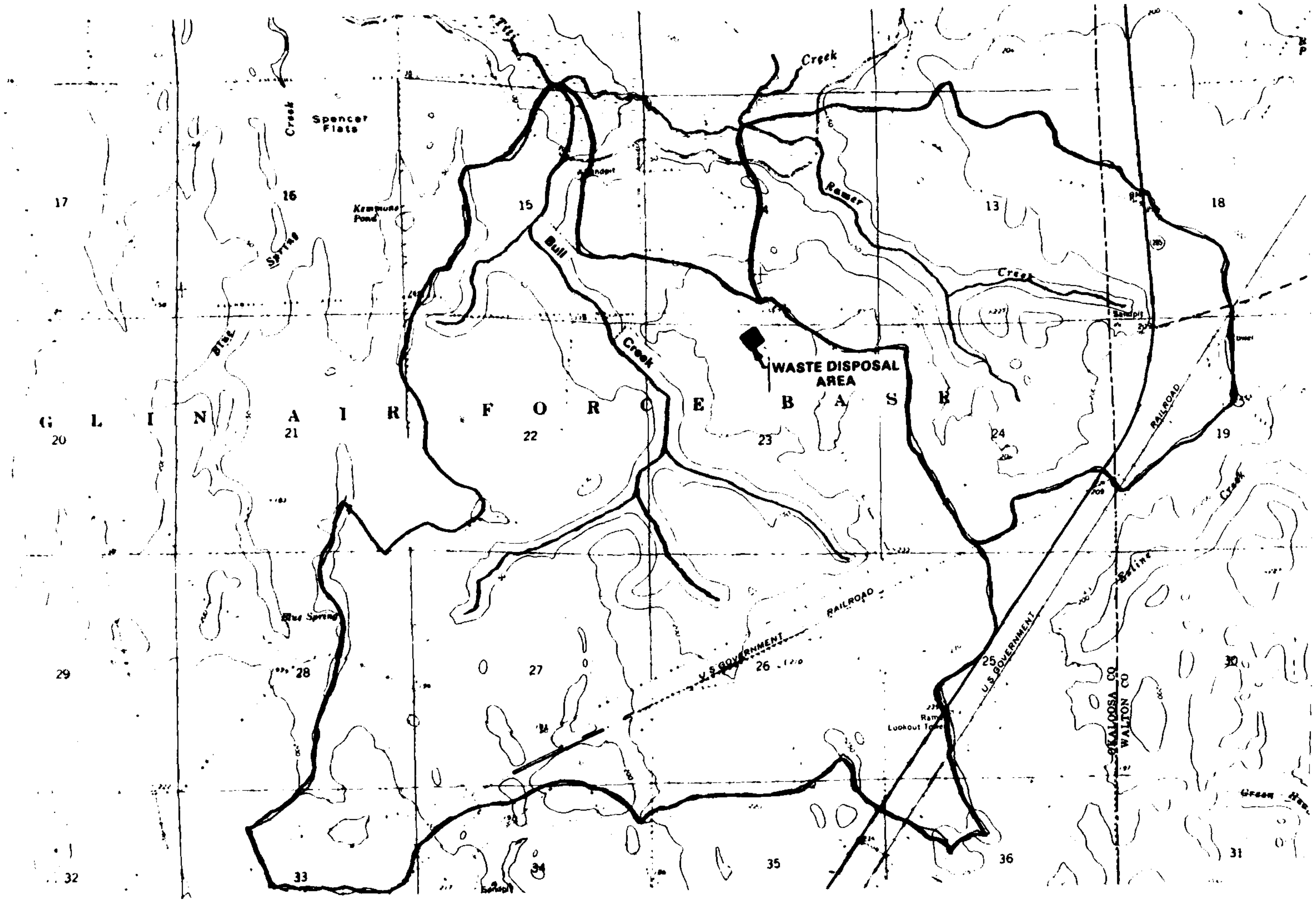


Figure E-2. Bull and Ramer Creek Drainage Basins and Site Location (taken from 7½' Spencer Flats usgs Quadrangle)

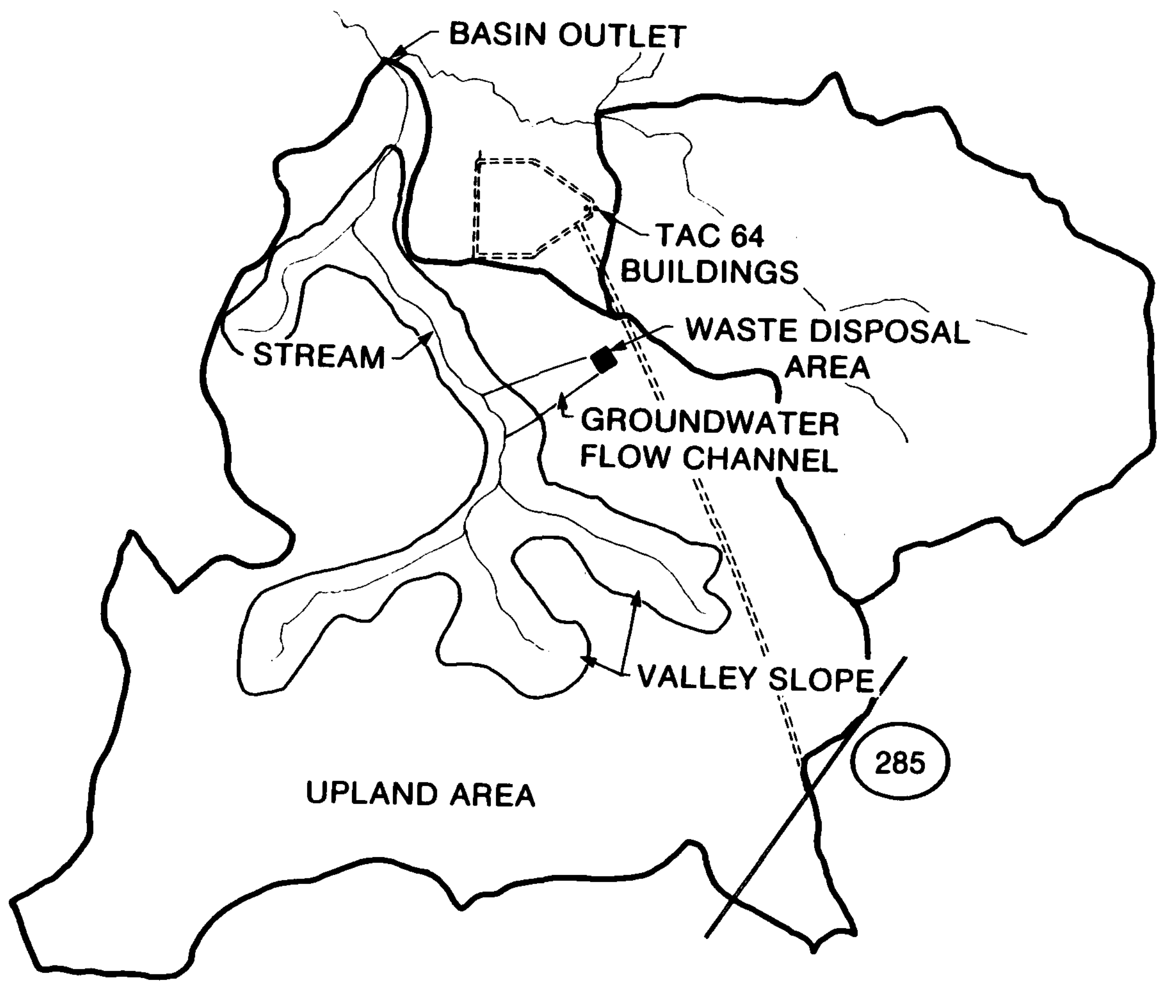


Figure E-3. Drainage Basin Map with Release Pathway Components

The precipitation which occurs from December through April is usually of the frontal type, providing widespread, long-duration rainstorms. From June through September, convective-type storms (afternoon and evening thunderstorms) are the predominant rain producing weather system (Reference E-6).

c. Hydrogeologic Setting

Middle Eocene and recent series sediments constitute the major aquifers and confining beds in the vicinity of TAC 64. Barr, et al. (Reference E-6), provide an excellent description of the geology and relate it to hydrologic characteristics of the rock units. The strata consist mostly of marine limestone, clay, and sand. The stratigraphic units, their approximate thicknesses, lithologic description and water-bearing characteristics are listed in Table E-1. The relationship between stratigraphy and hydrogeologic units is also given in Table E-1. The four main hydrogeologic units of concern in the vicinity are discussed below and are depicted in Figures E-4 and E-5.

The sand and gravel aquifer has a water table and is mainly used locally for irrigation. There are few domestic wells in the sand and gravel aquifer because of the low total dissolved solids and hence poor acid-base buffering of the water. This condition promotes low pH which causes water to corrode plumbing systems. It is not presently used for public water supplies other than for irrigation of golf courses and other public recreation facilities.

The Pensacola Clay confining bed separates the sand and gravel aquifer from the underlying upper limestone bed of the Floridan aquifer. This hydrogeologic unit consists of the strata shown in Table E-1. The Floridan aquifer is the

TABLE E-1. GEOLOGIC UNITS IN SOUTHERN OKALOOSA AND WALTON COUNTIES AND THEIR HYDROGEOLOGIC EQUIVALENTS

Years	Epoch	Stage	Formation	Thickness (ft.)	Lithologic Description	Hydrogeologic Unit	Hydrologic Characteristics
	Recent to Pliocene		Piliocene Recent Sands	50-250	Unconsolidated, white to light gray fine to medium guartz sand. Accessories include heavy minerals and phosphate.	Sand and Gravel Aquifer	Water mainly unconfined. In Fort Walton Beach, includes surficial unconfined unit and lower leaky artesian unit. Yields range from less than 20 gal/min in coastal lowlands of Walton County to 1000 gal/min in uplands of western Okaloosa County. Tapped by shallow wells for domestic supply and a few larger capacity wells for irrigation. Currently not used by municipal systems for public consumption.
			Citronelle Formation	50-250	Predominantly non-marine quartz sands with thin stringers of clay or gravel discontinuous over short distances.		
12×10^6			Miocene Coarse Clastics		Found only along the western portion of Okaloosa County. The Miocene coarse clastics are comprised of poorly consolidated sand, gravel, clay and shell beds.		
	Upper Miocene	Choctawhatchee	Intracoastal	0-360	Lithologically, the Intracoastal is made up of a poorly consolidated, sandy clayey, microfossiliferous limestone.	Pensacola Clay Confining Bed	Restricts vertical movement of water because of thickness and comparatively low permeability. In the* area of investigation grades laterally from dense clay and sandy clay in western part to clayey, silty sand in the eastern part. Not a source of water.
	Upper to Middle Miocene	Alum Bluff	Alum Bluff Group (Northern Portion Only)	0-300	The Alum Bluff occurs as a mixture of sands, clays and shell beds in relatively well sorted thin beds. The matrix material is commonly clay or carbonate cement.		
			Pensacola	0-190	In the western half of the study area, the Pensacola Clay interfingers with the Intracoastal Formation and Alum Bluff Group. The Pensacola is predominantly a bluish gray to olive gray, dense, silty clay.		

TABLE E-1. GEOLOGIC UNITS IN SOUTHERN OKALOOSA AND WALTON COUNTIES AND THEIR HYDROGEOLOGIC EQUIVALENTS (CONTINUED)

Years	Epoch	Stage	Formation	Thickness (ft.)	Lithologic Description	Hydrogeologic Unit	Hydrologic Characteristics
	Lower Miocene	Tampa	Bruce Creek Limerstone	20-220	Light gray to white in appearance, the Bruce Creek is moderately indurated, granular and occurs as a clastic limestone. Accessories include a sand fraction which increases north and east.	Upper Limestone of the Floridan Aquifer	Principal source of water in* area of investigation. Yields large quantities of fresh water under confined conditions. Yields range from 250 gal/min to over 1000 gal/min. Sustained yields are generally lowest immediately adjacent to the coast in Okaloosa County. Individual zones vary greatly in permeability and vertical hydraulic connection. Contains over 250 ppm chlorides in parts of southeastern Walton and southwestern Okaloosa counties.
20×10^6 yr			Tampa Stage Limestones	30-140	Lithologically, similar to Chickasawhay Limestones but slightly less dolomitic. Silt and clay content increase towards the top of the formation.		
	Upper Oligoncene	Vicksburg	Chickasawhay	30-260	Primarily a tan sucrosic dolomite but may also occur as a cream to buff fossiliferous limestone.		
	Middle to Lower Oligocene		Bucatunna Clay-Member of Byram Formation	0-130	The Bucatunna is a medium brown to dusky, yellowish-brown calcareous clay. Accessories include up to 10 percent phosphate. The top contact of the Bucatunna Clay is sharp and well defined from the overlying limestone.	Bucatunna Clay Confining Bed	Where present, restricts vertical movement of water between overlying and underlying hydrogeologic units. Generally present in coastal Walton and Okaloosa counties but absent in northern parts of area.
35x10yr							
	Upper Eocene	Jackson	Ocala Group Limestones	165-600	A white to light gray, chalky, fossiliferous relatively pure calcium carbonate limestone. Occasionally the limestone is interlayeded with thin streaks of light brown or tan dolomite.	Lower Limestone of the Foridan Aquifer	Comprises a separate hydrogeologic unit in coastal Walton and Okaloosa counties. In other parts, cannot be hydrologically distinguished from upper limestone area.

TABLE E-1. GEOLOGIC UNITS IN SOUTHERN OKALOOSA AND WALTON COUNTIES AND THEIR HYDROGEOLOGIC EQUIVALENTS (CONCLUDED)

Years	Epoch	Stage	Formation	Thickness (ft.)	Lithologic Description	Hydrogeologic Unit	Hydrologic Characteristics
45-50x 10^6yr	Middle Eocene	Claiborne	Lisbon/ Tallahha Formations	345-500 170-300	Massive shaly with chalky limestones often dark gray to crean in color. Thin shaly beds predominate in the more calcareous portions.	Caliborne Confining Unit	Predominately impermeable strata. Comprises the base of the ground-water flow system.

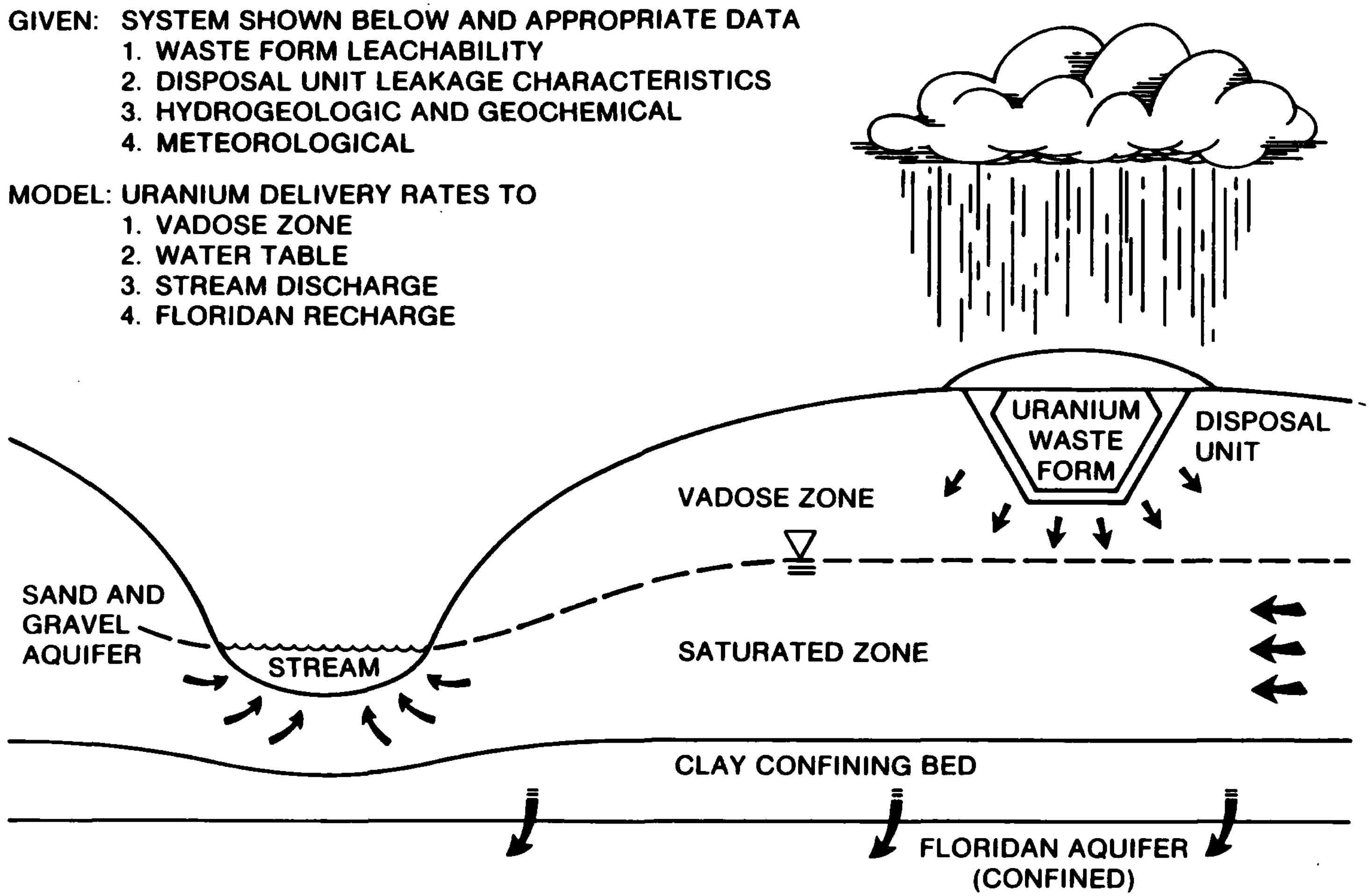


Figure E-4. Hydrogeologic Cross Section and Groundwater Pathway

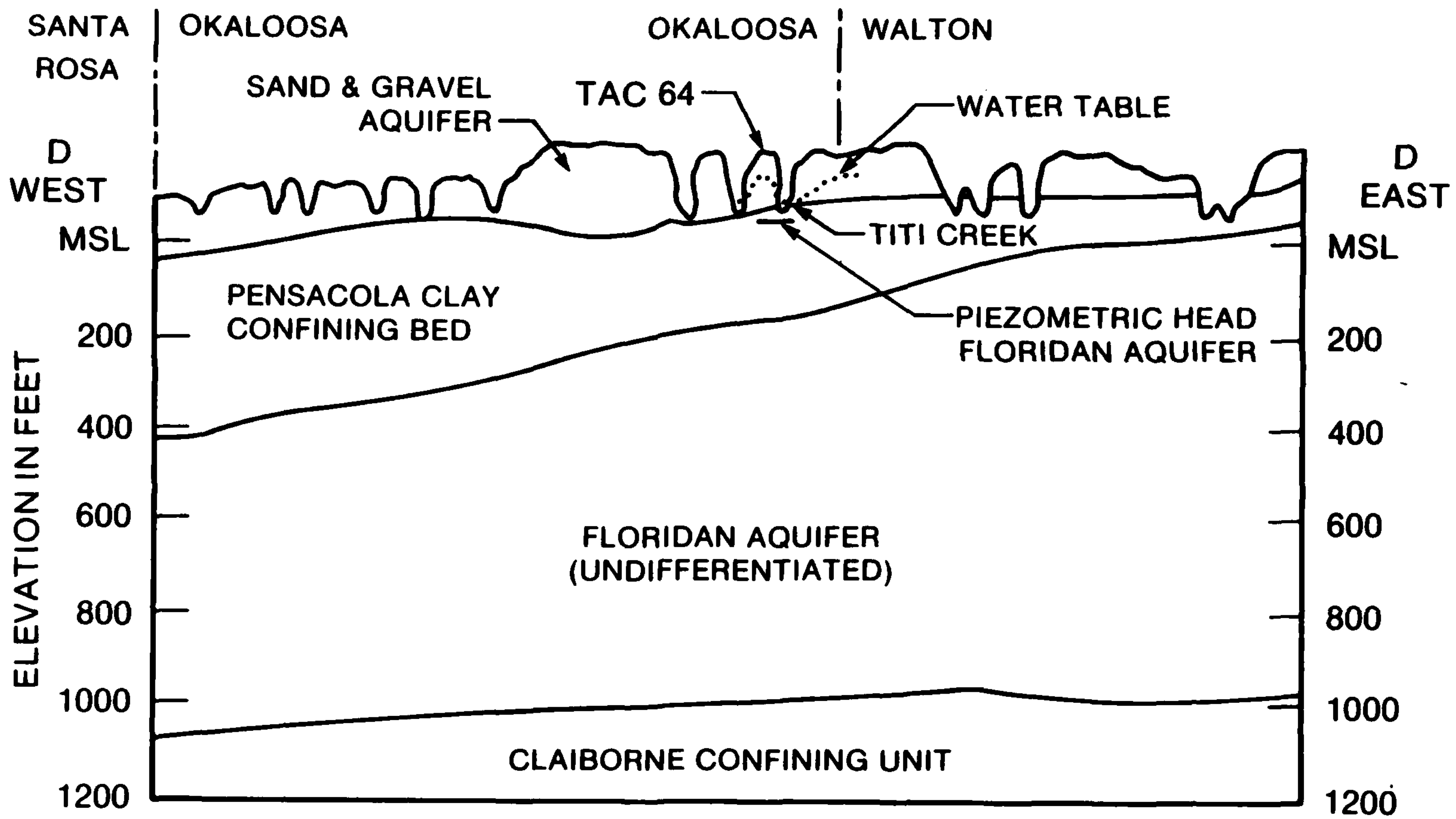


Figure E-5. Hydrologeologic Cross Section Through TAC 64 Vicinity

main water supply in the area. It consists of thick and extensive sequences of interbedded limestones and dolomites of Upper Eocene to Miocene ages. Specific strata are listed in Table E-1. Groundwater storage and movement in the limestone of the aquifer is through a combination of small solution fissures and larger cavities and solution channels. The aquifer is confined in the site vicinity. The Bucatunna clay confining bed probably does not exist under the site vicinity but develops somewhere south and east of the site.

The Claiborne confining unit is a shaley, chalky limestone of low permeability that forms the base of the groundwater flow system (Reference 6).

d. Hydrology and Hydrogeology

The general hydrogeologic system is simple and is schematically depicted in Figure E-4. In this hydrogeologic setting, described in the previous section, with the presence of few heavily pumped wells, the surface drainage divides for the sand and gravel aquifer are probably very close to the groundwater divides. Preliminary analysis of both the water table configuration and the proximity of the Pensacola Clay confining bed to the stream bottoms indicates that the streams are discharge boundaries. A detailed site characterization study would specifically search for data to accurately determine the boundaries of the local water table system. With existing head conditions, water leaks through the Pensacola Clay confining bed into the Floridan aquifer. Leakage from the sand and gravel aquifer into the Floridan aquifer in the Ft. Walton Beach Area averages approximately 2-3 million gallons/day based on the results of model studies (Reference E-6). This represents less than 10 percent of the total groundwater flow coming from upgradient areas. All precipitation falling within, for example, Bull Creek basin will

ultimately be disposed of as: 1) evapotranspiration, 2) groundwater discharge into Bull Creek, and 3) leakage into the Floridan aquifer.

The present location of the drum storage yard is too close to the groundwater divides between Titi and Bull Creeks to predict a flow direction in the ground water system. Consequently, the potential disposal site should be located as indicated on Figure E-3 approximately 0.6 mile south of the cannon test buildings, 0.1 to 0.2 mile due west of the North-South access road. This location places the site in the Bull Creek watershed. Data for this watershed is shown in the table below.

	Basin Area (mi2)	Upland Fraction (%)	Valley Slope Fraction (%)	Average Annual Precipitation (inches)	Et* (in/yr)	Discharge (in/yr)
Bull Creek	6.73	83	17	61	30	31
Ramer Creek	2.8	NA	NA	61	30	31
South bank of Titi Creek between confluences with above streams	0.52	NA	NA	61	30	31

*Evapotranspiration

This location is the most desirable because its greater watershed area will provide more dilution potential than a location in either Ramer Creek Basin or Titi Basin to the east and north, respectively. It is also well into upland area, and consequently, depths to the water table are optimized. In this setting the stream surface is at the elevation of the water table. The slope of the water table will be no more than 10 feet/1000 feet or nearly flat. The sand and gravel aquifer is slightly more than 150 feet thick

at the TAC-64 site. The approximate potentiometric elevation at that site is 130 feet (Reference E-6). Since the surface elevation at TAC-64 (Drum Storage Area) is 200 feet above sea level, the distance to the water table is on the order of 70 feet. The saturated thickness of the aquifer is about 80 feet.

Great care should be taken to locate the site clearly in a single basin to avoid the possibility of leachate flowing in two different directions. Single-basin location is also critical in choosing a location for the potential site because in Titi Basin, there is no clearly defined stream along which to intercept contaminated discharge. The ground water probably flows directly into the wetland area in the Titi Valley.

The upland portion of Bull Creek Basin will likely produce little or no direct surface runoff; most precipitation either becomes evapotranspiration or ground water recharge. Thus the surface water pathway for waste release is not significant. The valley slope areas will produce surface run-off on occasions in their steeper areas where soil has enough clay content to retard normally high infiltration rates. Because of these differences, the portion of the groundwater flow channel depicted in Figure E-3 that is downslope of the upland/valley slope boundary will probably get dilution less than that predicted by the surface area relationships. Because the surface runoff enters the stream at the same location as the ground water flow channel, it will be hard to detect the concentration differences that may result from these particular basin characteristics.

4. EQUILIBRIUM GEOCHEMISTRY AND URANIUM SPECIATION AT THE POTENTIAL SITE

Uranium speciation (by which concentration in an aqueous environment is controlled) is governed by three variables;

- o oxidation-reduction potential,
- o pH, and
- o total carbonate (open systems) or pCO_2 (closed systems).

Some of the resulting reactions that must be considered in the uranium-water-carbonate system are discussed in the following sections.

a. Geochemistry

The starting materials in the waste are either uranium metal (U), uranium dioxide (UO_2) and/or mixed oxides from U_3O_8 to UO_3. Uranium metal in the presence of moisture will react to form UO_2.

$$U + 2H_2O \rightarrow UO_2 + 2H_2$$

UO_2 under the proper oxidizing conditions (Eh* approximately greater than 0.5) will yield to UO_2^{+2}(uranyl ion).

$$UO_2 \rightarrow UO_2^{+2} + 2e^-$$

*This symbol indicates the redox or oxidation-reduction potential of a redox system. It can be related to dissolved O_2 measured in aqueous solutions in the field.

Under other conditions UO_2 can be converted to U_3O_8, but this will probably not occur in the expected pH range; a pH >8 is probably needed (Reference E-7).

If uranium metal is placed in an excess of air, it will react to form a higher oxide as demonstrated by yellow and greenish oxides present on penetrated armor plate and U_3O_8 detected on penetrated armor plate (Reference E-8). The most likely chemical reaction course for the majority of the waste is U to UO_2 to UO_2^{+2} if Eh and pH conditions are appropriate.

In the absence of carbon dioxide, pH and dissolved O_2 (or Eh) together control uranium solubility and speciation. The presence of and concentration of HCO_3^{-1} and/or CO_3^{-2} adds a third control. Uranium forms several complex ions in the presence of CO_2 or carbonates which will increase its solubility by several orders-of-magnitude as is demonstrated by the comparison of the three wells in the sections that follow (References E-9, E-10 and E-11).

b. Uranium Speciation

In this section, the water chemistry of three wells selected for their similarity of location to the proposed site will be examined with the goal of predicting uranium speciation. No Eh (or dissolved O_2) data has been found for the site vicinity; consequently, some values must necessarily be assumed. To be conservative, slightly oxidizing conditions are assumed for the vadose zone, and neutral or slightly reducing conditions are assumed to develop at or below the water table. It should be noted that copious abundance of the organic material in the first layers of the vadose zone could consume O_2 and lower the Eh to a reducing environment

very rapidly. Nevertheless, in lieu of hard data, +0.2, 0, -0.2 Eh values are assumed for the sampled wells.

Barr, et al., (Reference E-6) provide a comprehensive view of the best and most current water quality data available for the sand and gravel aquifer in the terrain around Eglin Air Force Base. Wells producing in this hydrogeologic unit are not available in the vicinity of TAC-64. However, three wells producing in this unit set in similar terrain but away from the proposed site are numbers 222, 224 and 279. Table E-2 tabulates the concentration values in these wells for chemical species that can impact on uranium concentration in the wells. The listed equilibrium expressions are used to calculate carbonate concentration, and then total carbonate species are computed.

Ultimately, if field-collected Eh or dissolved oxygen data are available, equations from Pourbaix (Reference E-6) can be used to calculate the stable uranium species for each sample. For simplicity and time saving, with this sample data the stable species can be graphically determined from stability diagrams taken from Garrels and Christ, and Langmuir (References E-9 and E-10).

The stability plots depicted in Figures E-6 and E-7 are taken from Garrels and Christ (Reference E-9). Paraphrasing the authors' words: they "compare the effect of CO_2 on uranium solubility in the open system (P_{CO}) and the closed system (ΣCO_2). In both instances, hexivalent uranium is complexed strikingly as the uranyl dicarbonate and uranyl tricarbonate ionic species, so that with appreciable (P_{CO}) or ΣCO_2, the field of stability of the uranyl oxide hydrate is wiped out. These complexes are so effective that they 'eat' down into the field of stability of UO_2 (uraninite) when (P_{CO}) and ΣCO_2 are relatively high. It should be clear

TABLE E-2. EXISTING CHEMICAL DATA APPLICABLE TO URANIUM SPECIATION

WELL* NO.	pH*	HCO_3^{-}* (mg/L)	TDS* (mg/L)	$[HCO_3^{-}]$ gm moles/L	$[CO_3^{-2}]$ gm moles/L	TOTAL CARBONATE SPECIES
222	5.7	5	22	8.2×10^{-5}	2.06×10^{-9}	$10^{-4.09}$
224	4.6	0	26	0	0	
279	6.1	41	69	6.72×10^{-4}	4.24×10^{-8}	$10^{-3.17}$

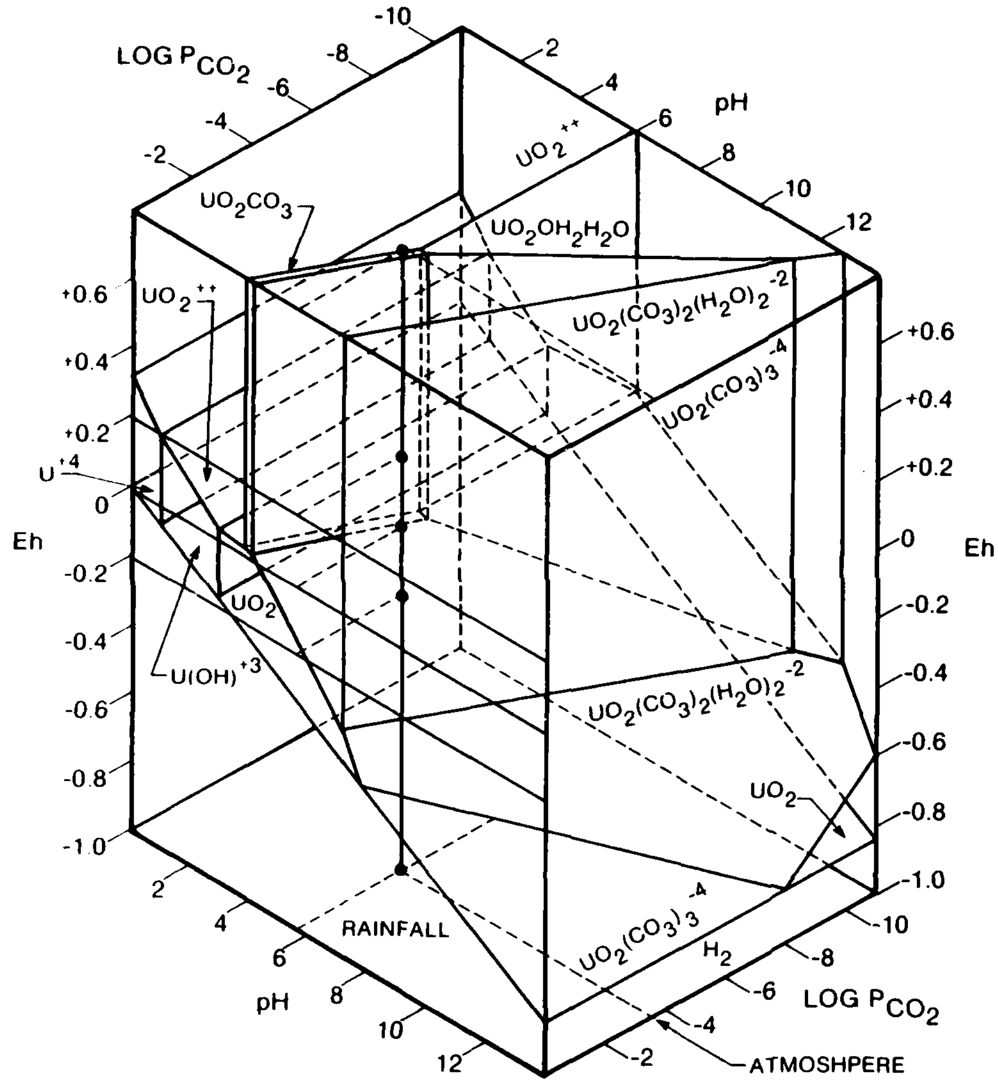
$[H^+]$ AND $[HCO_3^-]$ ARE SUBSTITUTED IN

$$10^{-10.3} = [H^+][CO_3^{-2}]/[HCO_3^-]$$

TO CALCULATE THE $[CO_3^{-2}]$

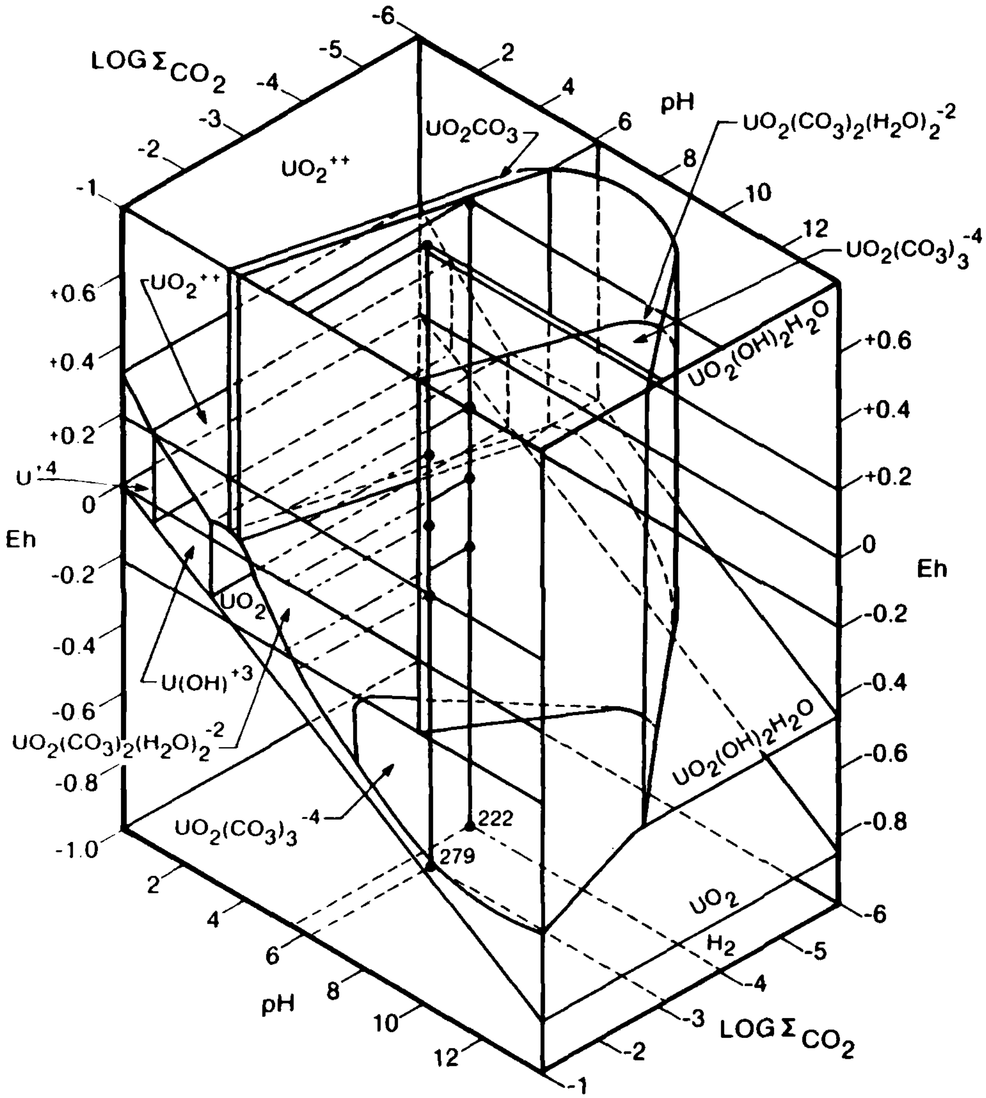
IN BOTH CASES THE CARBONATE CONTRIBUTION IS INSIGNIFICANT IN THE SUM OF CARBONATE SPECIES (ΣCO_2) IN THE WATER.

*DATA EXTRACTED FROM
BARR D.E., et al, "WATER RESOURCES OF SOUTHERN OKALOOSA AND WALTON COUNTIES, NORTHWEST FLORIDA," WATER MANAGEMENT DISTRICT WATER RESOURCES ASSESSMENT 81-1.



STABILITY RELATIONS AMONG SOME URANIUM COMPOUNDS IN WATER AT 25°C AND I ATMOSPHERE TOTAL PRESSURE AS A FUNCTION OF pH, Eh, AND P_{CO_2}. BOUNDARIES OF SOLIDS AT ACTIVITY OF TOTAL DISSOLVED URANIUM-BEARING SPECIES OF 10^{-6}. (COURTESY R. GARRELS, P. HOSTETLER, A. WEEKS, C. CHRIST)

Figure E-6. Uranium Specification in Water as Function of pH, Eh and PCO_2^-



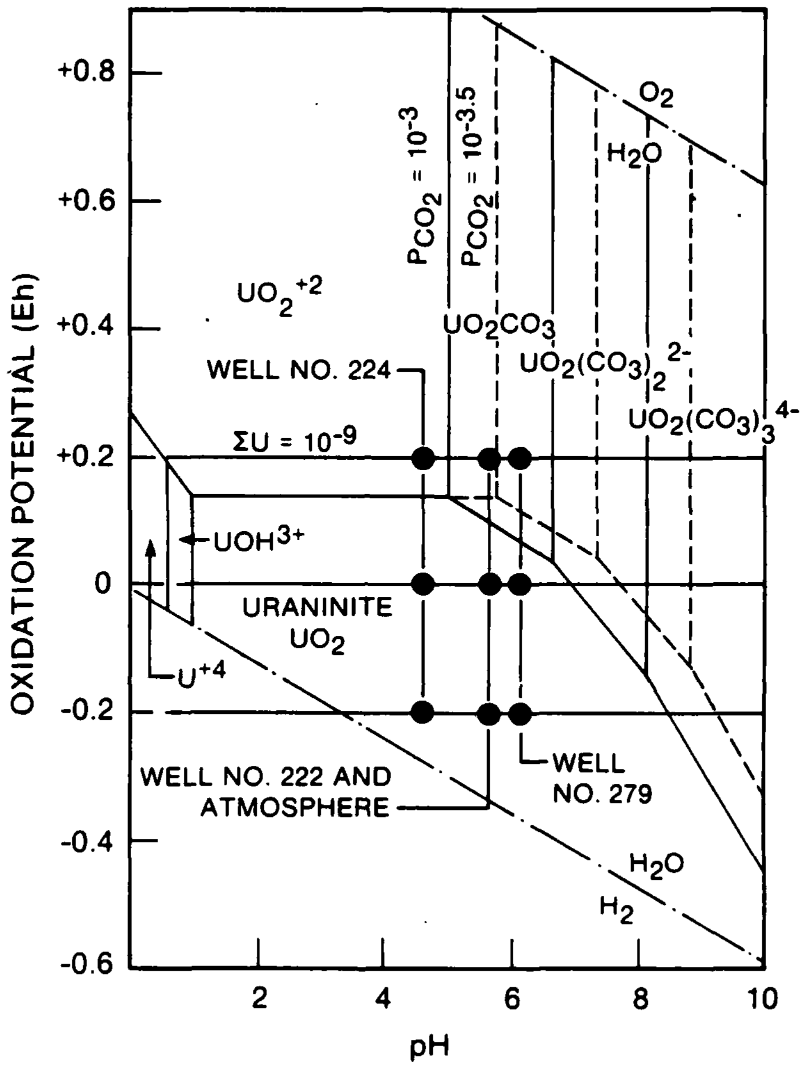
STABILITY RELATIONS AMONG SOME URANIUM COMPOUNDS IN WATER AT 25°C AND I ATMOSPHERE TOTAL PRESSURE AS A FUNCTION OF pH, Eh, AND TOTAL DISSOLVED CARBONATE SPECIES. BOUNDARIES OF SOLIDS AT ACTIVITY OF TOTAL DISSOLVED URANIUM-BEARING SPECIES OF 10^{-6}. (COURTESY R. GARRELS, P. HOSTETLER, A. WEEKS, C. CHRIST)

Figure E-7. Uranium Specification in Water as a Function of pH, Eh and Total Dissolved Carbonate Species

that carbonate-bearing solutions are excellent solvents for uranium." Figures E-8 and E-9 are taken from Langmuir (Reference E-10). Both references relate to geochemical equilibria regarding ore deposits. As such they represent low temperature aqueous geochemical equilibria and are applicable to the sand and gravel aquifer situation.

Figure E-6 is utilized to plot rainfall at the three chosen Eh values (-0.2, 0, +0.2). Figure E-7 plots wells #222 and #279 at the same Eh values. Values for well #224 were picked off the rear plane of Figure E-7. All points taken from Figures E-6 and E-7 are approximate, and this may account for some of the differences observed between species selected using the text by Garrels and Christ when compared to species selected from the Langmuir paper (Reference E-10). Figures E-8 and E-9 each represent a specific uranium concentration. The values for rainfall and the three wells are also plotted on Figures E-8 and E-9. Uranium speciation predicted by both Garrels and Christ, and Langmuir (References E-9 and E-10) is summarized in Table E-3.

UO_2 is generally considered very sparingly soluble to insoluble. All other uranium species in Table E-3 are soluble in water to varying degrees which are documented. Rain would fall with at least a mildly oxidizing Eh and would have the potential to produce uranyl (UO_2^{++}) or uranyl carbonate ($UO_2(CO_3)_2^{-2}$) as the stable uranium phase. As the water infiltrates into the vadose zone, organic matter would decay and remove dissolved O_2, lowering the Eh. Conditions for UO_2 stability begin to exist in the wells as the redox potential nears zero. Although moving toward UO_2 stability and precipitation of solid compound is desirable, according to some, fixation of uranium is unlikely because reaction kinetics of the <u>in-situ</u> reduction are less than favorable



$U = 10^{-9}$ (0.28 ppb)
$P_{CO_2} = 10^{-2}$ (SOLID LINES)
$P_{CO_2} = 10^{-3}$ (DASHED LINES)

Figure E-8. Eh-pH Diagram for the System $U\text{-}O_2\text{-}CO_2\text{-}H_2O$ (25°C)
Uranium Concentration = 0.28 ppb

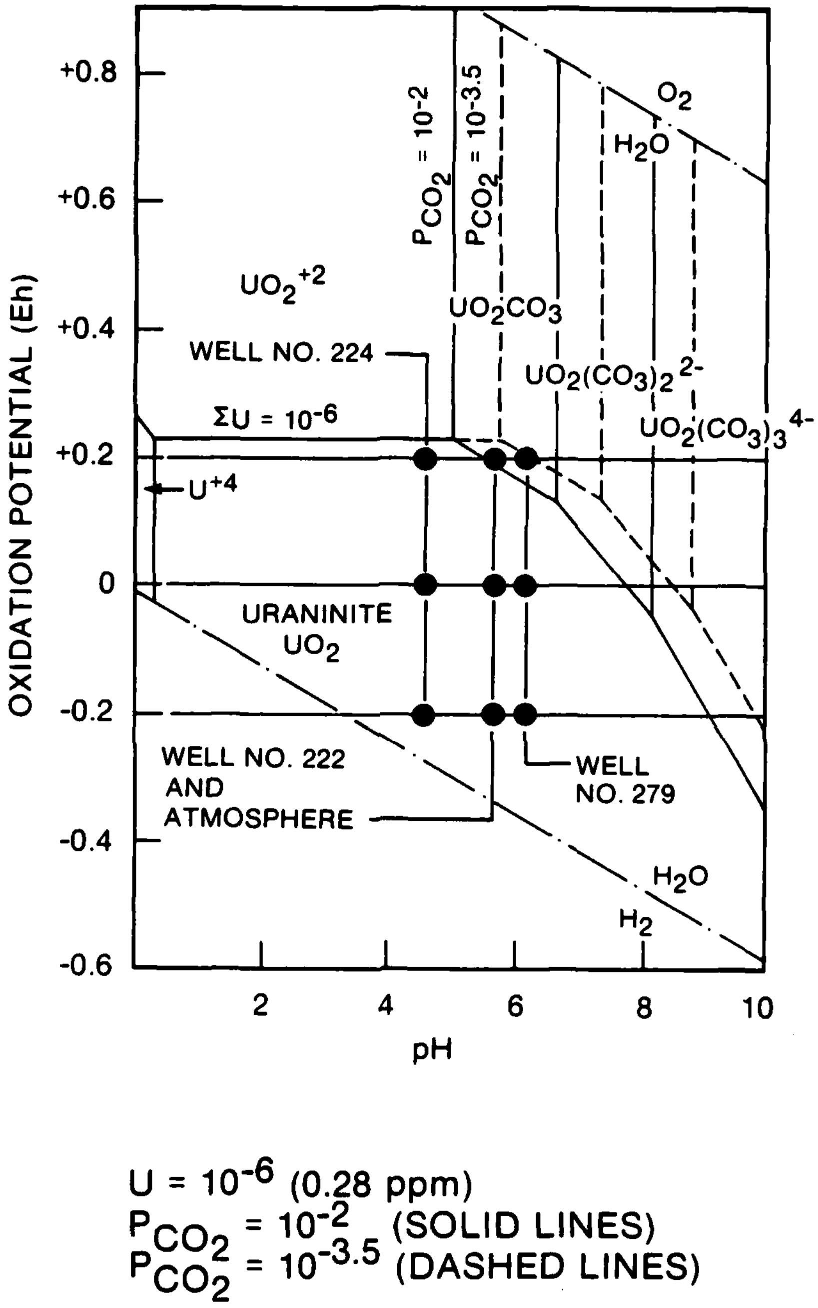


Figure E-9. Eh-pH Diagram for the System U-O_2-CO_2-H_2O (25°C) Uranium Concentrations 0.28 ppm

TABLE E-3. SUMMARY OF URANIUM SPECIATION DATA FOR THREE WELLS ON EGLIN RESERVATION

Eh (VOLTS)	RAIN WATER A	RAIN WATER B*	WELL NO. 222 A	WELL NO. 222 B*	WELL NO. 279 A	WELL NO. 279 B*	WELL NO. 224 A	WELL NO. 224 B*
+0.2	UO_2^{+2} OR UO_2CO_3	*UO_2^{+2}	$UO_2(CO_3)_2(_2O)_2^{-2}$	*UO_2CO_3	$UO_2(CO_3)_2(H_2O)_2^{-2}$	*UO_2CO_3	UO_2^{+2}	*UO_2^{+2}
0	$UO_2(CO_3)_2(H_2O)_2^{-2}$	UO_2	$UO_2(CO_3)_2(H_2O)_2^{-2}$	UO_2	$UO_2(CO_3)_2(H_2O)_2^{-2}$	UO_2	UO_2	UO_2
	UO_2		UO_2		UO_2			
-0.2	UO_2	UO_2	$UO_2(CO_3)_2(H_2O)_2^{-2}$	UO_2	$UO_2(CO_3)_2(H_2O)_2^{-2}$	UO_2	UO_2	UO_2
			UO_2		UO_2			

* ACCORDING TO B, SOME STABILITY BOUNDARIES ARE URANIUM CONTENTRATION DEPENDENT. AS CONCENTRATION INCREASES THE INDICATED SPECIES SHIFT TO UO_2.

A — GARRELS, R.M. AND C.L. CHRIST, "SOLUTIONS, MINERALS AND EQUILIBRIA"
B — LANGMUIR, D. "URANIUM SOLUTION-MINERAL EQUILIBRIA AT LOW TEMPERATURES WITH APPLICATIONS TO SEDIMENTARY ORE DEPOSITS"

(Reference E-11). With sufficient carbonate present, uranium will remain mobile at Eh values as low as -0.1 (Reference E-12).

c. Solubility Limitations

Uranyl hydroxide equilibrium and, in the presence of carbonates, uranyl carbonate, are the two mechanisms which can control uranium solubility in the sand and gravel aquifer.

The reactions that control uranium solubility are taken from Krauskopf (Reference E-12) and are for hydroxide controlled systems:

$$UO_2(OH)_2 \rightleftarrows UO_2OH^+ + OH^- \qquad k = 10^{-14.2}$$

$$UO_2(OH)^+ \rightleftarrows UO_2^{+2} + OH^- \qquad k = 10^{-8.2}$$

$$UO_2(OH)_2 + 3OH^- \rightleftarrows UO_2(OH)_3^- \qquad k = 10^{-3.6}$$

$$UO_2 + 2H_2O \rightleftarrows U^{+4} + 4OH^- \qquad k = 10^{-56.2}$$

The equilibrium expressions for these reactions can be solved for the contribution that each species UO_2^{2}, UO_2OH^+, $UO_2(OH)_3^-$ and U^{+4} will make to a saturated, equilibrated system at the field-measured pH. The calculations have been performed and results are summarized in Table E-4.

For a carbonate-controlled system the following reactions apply:

$$UO_2(CO_3)^{-2} \rightleftarrows UO_2^{+2} + 2CO_3^{-2} \qquad k = 10^{-14.6}$$

$$UO_2(CO_3)_2^{-2} \rightleftarrows UO_2CO_3(s) + CO_3^{-2} \qquad k = 10^{-4.0}$$

$$UO_2(CO_3)_3^{-4} \rightleftarrows UO_2(CO_3)_2^{-2} + CO_3^{-2} \quad k = 10^{-3.8}$$

The equilibrium expressions for these reactions can be solved for the contribution that each species (UO_2^{+2}, $UO_2(CO_3)^{-2}$ and $UO_2(CO_3)_3^{-4}$) will make to a saturated, equilibrated system at the field measured pH and bicarbonate concentrations. The bicarbonate concentrations through the equation in Table E-2 give the carbonate concentrations for the above reactions. These values are combined with equilibrium expressions derived from the above equations in order to calculate the moles of uranium that can be dissolved at the given conditions. These calculations have been performed, and the results are summarized in Table E-4.

These saturation values will provide a conservative estimate of the upper limit to the amount of uranium that can be held in the groundwater; however, the Eh conditions of stability must be met for any species to be stable. It is assumed for the purpose of this conservative evaluation that all species in each equilibrium scenario are stable.

5. RELEASE SCENARIO

As suggested in previous sections, the main release pathway is via groundwater transportation in the surface groundwater system of the sand and gravel aquifer. A source term is developed for the waste forms, and a volumetric dilution model is developed for the drainage basin. Sorption and retardation are assumed, conservatively, to be negligible. The model produces uranium concentrations at identifiable points on the release pathway. These concentrations are then converted to doses in a subsequent section.

TABLE E-4. URANIUM SATURATION LEVELS IN SELECTED WELLS

Hydroxide Control
moles/liter

Well #	pH	$[OH^-]$	$[UO_2^{+2}]$	$[UO_2OH^+]$	$[UO_2(OH)_3^-]$	$[U^{+4}]$	Total Moles	mg/l
222	5.7	$10^{-8.3}$	$10^{-5.8}$	$10^{-5.9}$	$10^{-36.8}$	$10^{-23.0}$	2.84×10^{-6}	0.68
279	6.1	$10^{-7.9}$	$10^{-6.6}$	$10^{-6.3}$	$10^{-35.2}$	$10^{-24.6}$	7.52×10^{-7}	0.18

Carbonate Control
moles/liter

Well #	pH	$[CO_3^{-2}]$	$[UO_2^{+2}]$	$[UO_2(CO_3)_2^{-2}]$	$[UO_2(CO_3)_3^{-4}]$	Total Moles	mg/l
222	5.7	$10^{-8.69}$	$10^{-1.91}$	$10^{-4.69}$	$10^{-9.58}$	1.23×10^{-2}	2930
279	6.1	$10^{-7.37}$	$10^{-3.23}$	$10^{-3.37}$	$10^{-6.94}$	1.02×10^{-3}	242

a. Waste Form and Its Survivability

The waste form consists of a Portland cement-waste mixture designed with a hydraulic conductivity of 10^{-8} cm/sec cast into a high-density polyethylene mold shaped like a right-hexagonal prism. The waste forms are approximately 9 feet in diameter and 8.5 feet in height. The waste mixture and casting technique will be optimized to minimize the probability of the development of any secondary permeability in the waste form through cracking of the concrete mixture during and after curing. The following section indicates the causes of cracking and suggests mitigative measures.

b. Causes of Cracking in Concrete Waste Forms

This section presents a brief summary of the causes and suggests possible means of prevention of cracking in concrete structures in general, with specific application to the waste forms discussed herein. The first two causes discussed below apply to plastic (wet, or just poured) concrete; the others apply to hardened concrete.

(1) Plastic Shrinkage Cracking.

(a) Cause:
As concrete begins to cure, after pouring, consolidation, and prior to surface finishing, water evaporating from the surface faster than it can be replaced by bleed water causes shrinkage near the surface, with tensile stresses and resultant cracks developing in the stiffening surface layers.

(b) Possible Solution:
Plastic waste form molds, sunshades, and windbreaks can be used to retard evaporation and prevent rapid moisture loss.

(2) Settlement Cracking.

(a) Cause:
Differential slumping can occur in just poured concrete because of local restraint by rebars, etc. Continuous hardening then builds in tensile stresses and can cause cracks.

(b) Possible Solution:
These can be prevented by careful consolidation and use of concrete formulations with the lowest possible slump. Careful processing and proper handling will prevent settling. The care may include an entrainment of the mixture.

(3) Drying Shrinkage.

(a) Cause:
During and after curing, water may still be lost from the cement gel constituent of the concrete. The resulting volume change is resisted, either by the aggregate or by the subgrade. The tensile forces thus generated, if they exceed material tensile strength, cause shrinkage cracks.

(b) Possible Solution:

Drying shrinkage can be reduced by using the maximum possible amount of aggregate, minimum water/concrete ratio, use of shrinkage compensating cements, or by sealing the surface to prevent loss of moisture. Obviously, a concrete intended for use in a high relative humidity or moist environment will be much less subject to shrinkage cracking than if used otherwise. The proposed high density polyethylene mold with lid will virtually stop drying.

(4) Thermal Stresses.

(a) Cause:

Temperature differences within a concrete structure can be generated by changes in ambient conditions or by heat of hydration effects or by both. The resultant differential volume changes generate tensile stresses, which, if sufficiently large, can cause cracking. The more massive the structure, the greater the susceptibility to this kind of damage.

(b) Possible Solution:

The cement used should be a low heat of hydration type. When buried, these monoliths will not be subject to large or sudden temperature swings, but during the time, if any, when they remain unburied, they should be maintained at as near a

constant temperature as practicable. This may include casting wasteforms in the burial position and partially back-filling the sides and top of the waste-form after a day or two of setting time.

(5) Chemical Reactions.

(a) Cause:
Concrete may crack because of internal expansion processes, as from the alkali-silica reaction, or from attack by ground waters, such as those containing large amounts of sulfate ion.

(b) Possible Solution:
Control measures include use of pozzolans, use where sulfate resistant cements are indicated, avoiding reactive aggregates, use of low alkali cement specifications, and surface sealing. In the present case, trench backfill should be specified to be low in alkalis, soluble sulfate, and other aggressive chemicals.

(6) Weathering Damage

(a) Cause:
This results from freeze-thaw cycles, heating-cooling cycles, and wet-dry cycles.

(b) Possible Solution:
A waste form monolith will be protected if buried well below the frost line.

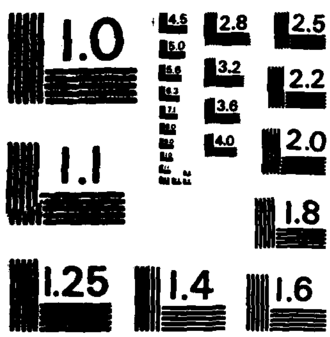
This is not a problem in Northwest Florida. If wet-dry cycles are a problem, a heavy surface coating would be ameliorative.

(7) Rebar Corrosion.

(a) Cause:
A corrosion product is generated whose specific volume exceeds that of the corroded-away metal, thus introducing internal tensile stresses. As corrosion proceeds and the volume of corrosion product grows, the stresses exceed the tensile strength of the concrete, and cracks occur. These cracks facilitate the corrosion process by admitting more aggressive chemicals, creating a positive feedback process.

(b) Possible Solution:
If the final waste form design and the operation scenario for waste placement can exclude wasteform reinforcing, the problem is avoided. If reinforcing is indicated, measures should be taken to prevent rebar corrosion. Use of rebar coating, low permeability cement, adequate rebar cover, and corrosion inhibitors are all potential solutions. Corrosion of rebars is least likely when the groundwater chloride content is low. If chloride attack is likely to be a problem, some form of cathodic protection might be considered.

AD-A166 739 ALTERNATIVES FOR DISPOSAL OF DEPLETED URANIUM WASTE(U) 3/3
WESTINGHOUSE HITTMAN NUCLEAR INC COLUMBIA MD
C W MALLORY ET AL. NOV 85 AFATL-TR-85-78
UNCLASSIFIED F08635-84-C-0333 F/G 18/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

In summary, resistance to cracking requires careful design and detailing, good construction practices, and the avoidance of overloads.

c. Waste Form Release Scenario

There is a lack of conventional leachability data for uranium in Portland cement waste forms. In the absence of leachability data, uranium solubility data can be used to conservatively estimate the rate at which water will remove uranium from the waste form. Further, the burial environment is not suitable for diffusion controlled leaching; the waste forms must be saturated or, in other words, standing in water. The waste forms at Eglin will be in the vadose zone and will as a result not be standing in water. For the purposes of this document, a plug flow model was envisioned where a wave of saturation moves down past a waste cylinder as a result of some rain event. This wave will interact with the waste form as dictated by its residence time in contact with the waste form, the waste form hydraulic conductivity, the soil hydraulic conductivity and the uranium species solubility in water.

In the model, water from each successive plug flow event will penetrate a shell of the wasteform. The shell thickness is controlled by the hydraulic conductivity of the waste and the time it takes for the plug to pass by a point on the waste form surface. This travel time is a function of the hydraulic conductivity of the medium which surrounds the cylinders. Successive plug flow events will continue to extract uranium from the same shell in quantities defined by the solubility limits until the uranium is completely removed. At that point, to be conservative, the shell will be arbitrarily removed and the process begins on the next shell.

In summary the model assumes that:

(1) waste forms are bare, without the high density polyethelene walls, bottom and top;

(2) waste forms are right circular cylinders;

(3) residence time for water in the shell is sufficient for uranium to dissolve;

(4) shell disappears when all of its uranium is removed;

(5) hydraulic conductivity of the soil is constant;

(6) water plug thickness is equal to inches of rain per rainfall distributed through the free area between cylindrical array;

(7) entire waste inventory (25 yr.) is placed in the ground at time equal to zero.

A computer program was developed for the model. A flow diagram for that code is shown in Figure E-10. The output and input variables are shown on Tables E-5 and E-6. The output indicated the mg/l uranium concentration of liquid delivered to the soil below the waste forms. The waste loading in the waste form was the maximum under 10CFR20.302. The concentrations of leachate delivered were based on carbonate-controlled solubility in well #222 equal to 2970 mg/l uranium and hydroxide-controlled solubility in well #222 equal to 0.68 mg/l uranium. These values were selected because they represented maximum values in each category among the three wells.

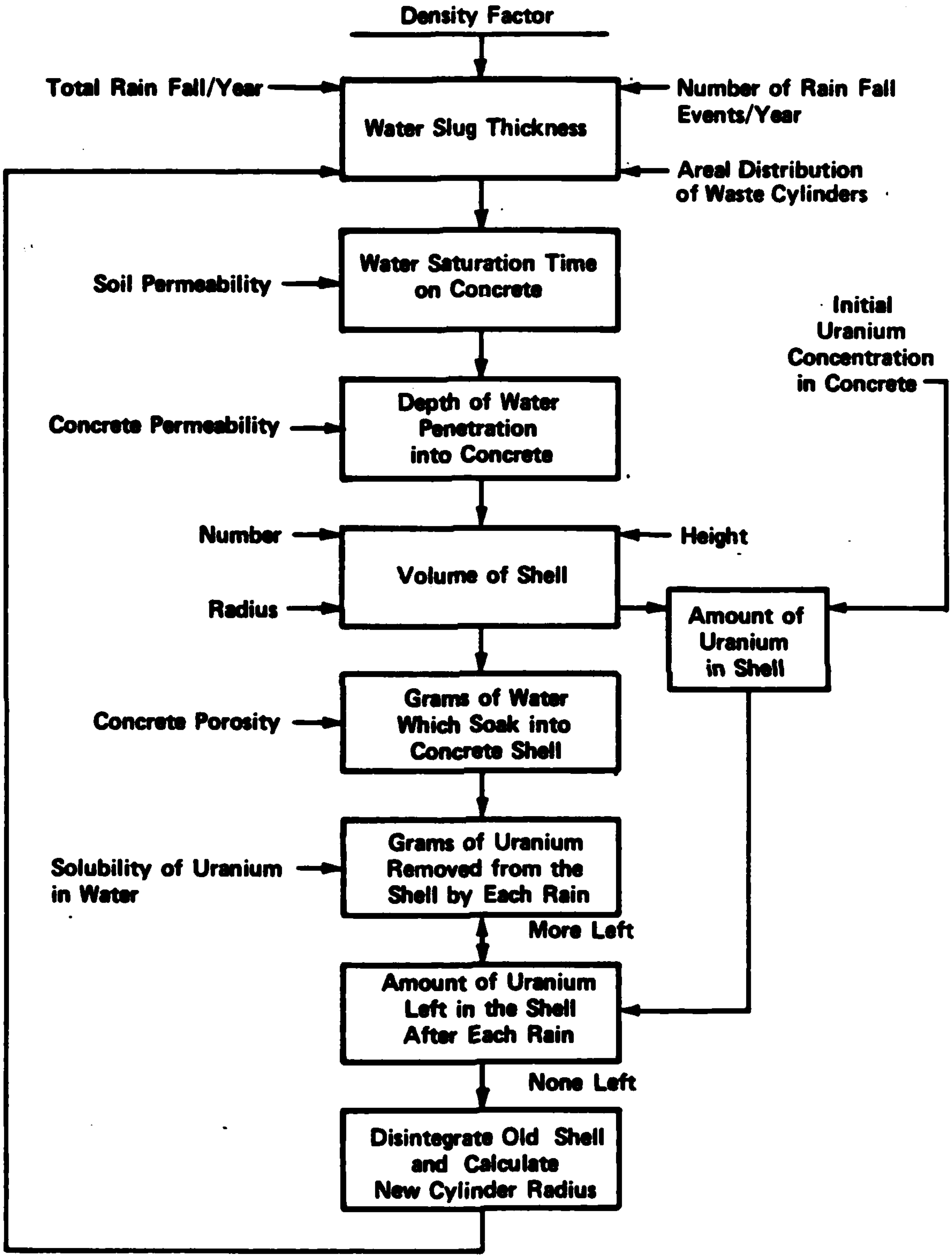


Figure E-10. Waste Form Release Source Model Computer Code Flow Chart

TABLE E-5. SOURCE RELEASE MODEL RUN INPUT AND OUTPUT AT URANIUM SOLUBILITY = 0.68 mg/l

EGLIN AIRFORCE BASE URANIUM RELEASE RATE USOL=2930.0

YEARS	U RELEASED PER YEAR (GRAMS)	AVERAGE CONCENTRATION (MG-U/L-WATER)	U RELEASED CUMULATIVE (GRAMS)	U-FRACTION RELEASED
1	1.6241E+01	4.9414E-03	1.6241E+01	1.4705E-07
10	1.6241E+01	4.9413E-03	1.6073E+02	1.4553E-06
100	1.6241E+01	4.9412E-03	1.6056E+03	1.4538E-05
1000	1.6236E+01	4.9398E-03	1.6052E+04	1.4534E-04
10000	1.6189E+01	4.9254E-03	1.6028E+05	1.4513E-03
100000	1.5734E+01	4.7871E-03	1.5800E+06	1.4306E-02
200000	1.4948E+01	4.5481E-03	3.1118E+06	2.8176E-02
300000	1.4828E+01	4.5115E-03	4.5989E+06	4.1640E-02
400000	1.4123E+01	4.2969E-03	6.0443E+06	5.4728E-02
500000	1.4041E+01	4.2719E-03	7.4509E+06	6.7463E-02
600000	1.3400E+01	4.0770E-03	8.8209E+06	7.9868E-02
700000	1.3347E+01	4.0609E-03	1.0157E+07	9.1963E-02
800000	1.2760E+01	3.8823E-03	1.1460E+07	1.0377E-01
900000	1.2467E+01	3.7930E-03	1.2733E+07	1.1529E-01
1000000	1.2446E+01	3.7868E-03	1.3978E+07	1.2656E-01

EGLIN AIRFORCE BASE URANIUM RELEASE RATE USOL=2930.0

RADIUS OF CYLINDER (IN)...............................	4.3200E+01
WEIGHT OF CYLINDER (IN)...............................	8.4000E+01
NUMBER OF CYLINDERS...................................	700
AREA ASSOCIATED WITH ALL CYLINDERS (SQ IN)..........	6.4700E+06
RAINFALL PER YEAR (IN/YR)............................	3.1000E+01
NUMBER OF RAINFALLS PER YEAR.........................	15
CONCRETE PERMIABILITY (CM/SEC).......................	1.0000E-08
VELOCITY OF WATER SLUG THROUGH SOIL (CM/SEC)........	1.0000E-02
NUMBER OF YEARS OF TRACKING..........................	1000000
CONCENTRATION OF URANIUM IN CONCRETE (G-U/CC-CONC)..	1.9550E-02
SOLUBILITY OF URANIUM (MG-U/LITER-WATER)............	2.9300E+03
GRAMS OF WATER PER CC OF CONCRETE...................	2.5000E-01
PRINT OPTION 0/N ALL YEARS/N SELECTED YEARS.........	15

SELECTED PRINTOUT TIMES (YEARS)

1 10 100 1000 10000 100000 200000 300000 400000
500000 600000 700000 800000 900000 1000000

TABLE E-6. SOURCE RELEASE MODEL RUN INPUT AND OUTPUT AT URANIUM SOLUBILITY = 2930 mg/l

EGLIN AIRFORCE BASE URANIUM RELEASE RATE USOL=0.68

YEARS	U RELEASED PER YEAR (GRAMS)	AVERAGE CONCENTRATION (MG-U/L-WATER)	U RELEASED CUMULATIVE (GRAMS)	U-FRACTION RELEASED
1	3.7693E-03	1.1468E-06	3.7693E-03	3.4128E-11
10	3.7693E-03	1.1468E-06	3.7693E-02	3.4128E-10
100	3.7693E-03	1.1468E-06	3.7693E-01	3.4128E-09
1000	3.7693E-03	1.1468E-06	3.7693E+00	3.4128E-08
10000	3.7692E-03	1.1468E-06	3.7692E+01	3.4128E-07
100000	3.7692E-03	1.1468E-06	3.7692E+02	3.4128E-06
200000	3.7692E-03	1.1468E-06	7.5384E+02	6.8255E-06
300000	3.7692E-03	1.1468E-06	1.1308E+03	1.0238E-05
400000	3.7691E-03	1.1468E-06	1.5077E+03	1.3651E-05
500000	3.7691E-03	1.1468E-06	1.8846E+03	1.7064E-05
600000	3.7691E-03	1.1467E-06	2.2615E+03	2.0476E-05
700000	3.7691E-03	1.1467E-06	2.6384E+03	2.3889E-05
800000	3.7690E-03	1.1467E-06	3.0153E+03	2.7301E-05
900000	3.7690E-03	1.1467E-06	3.3922E+03	3.0714E-05
1000000	3.7690E-03	1.1467E-06	3.7691E+03	3.4127E-05

EGLIN AIRFORCE BASE URANIUM RELEASE RATE USOL=0.68

RADIUS OF CYLINDER (IN).............................	4.3200E+01
HEIGHT OF CYLINDER (IN).............................	8.4000E+01
NUMBER OF CYLINDERS.................................	700
AREA ASSOCIATED WITH ALL CYLINDERS (SQ IN)..........	6.4700E+06
RAINFALL PER YEAR (IN/YR)...........................	3.1000E+01
NUMBER OF RAINFALLS PER YEAR........................	15
CONCRETE PERMIABILITY (CM/SEC)......................	1.0000E-08
VELOCITY OF WATER SLUG THROUGH SOIL (CM/SEC)........	1.0000E-02
NUMBER-OF YEARS OF TRACKING.........................	1000000
CONCENTRATION OF URANIUM IN CONCRETE (G-U/CC-CONC)..	1.9550E-02
SOLUBILITY OF URANIUM (MG-U/LITER-WATER)............	6.8000E-01
GRAMS OF WATER PER CC OF CONCRETE...................	2.5000E-01
PRINT OPTION 0/N ALL YEARS/N SELECTED YEARS.........	15

SELECTED PRINTOUT TIMES (YEARS)

1 10 100 1000 10000 100000 200000 300000 400000
500000 600000 700000 800000 900000 1000000

d. Pathway Analysis

Precipitation infiltrating over the entire waste area will flow past the waste forms and acquire uranium as discussed in the previous section.

This uranium-bearing solution or leachate is subsequently transported down through the vadose or unsaturated zone of the sand and gravel aquifer to the water table. Basin-controlled groundwater flow transports the leachate onward to stream discharge. A small fraction of the leachate will be diluted and may subsequently leak into the Floridan aquifer. Dilution, dispersion and sorption all act during this transportation process to lower leachate concentration; however, dilution only is considered here. To be conservative, no credit is taken for sorption or dispersion.

The release pathway can be divided into four components for evaluation. The outlet or drain for each component is a point where uranium concentration can be computed by dilution factor application to calculated leachate concentration. Three of these components and concentration calculation points are shown in Figure E-3. Leachate is produced in the waste disposal area and enters into the ground water flow channel where it flows to ground water discharge along the stream bank. The contaminant travels along the stream pathway to the drainage basin outlet. Because the surface is sandy and upland slopes are low, actual surface runoff can be expected to be minimal. Surface runoff may occur in valley slope areas or areas where the clay content of the soil reduces infiltration; but in upland areas, precipitation enters the ground. Data indicates that the average annual rainfall for the site is 61 inches. Thirty inches of this water is lost though evaportransporative (Et) losses

(References E-13 and E-14). The remaining 31 inches of annual water (infiltrate) is available to exit the waste disposal area as leachate.

As the leachate moves into the groundwater portion of the release pathway, it will be diluted by uncontaminated infiltrate. In this terrain the greatest portion of the 31 inches of annual rainfall infiltrating the flow channel will reach the ground water. A plume of uranium-bearing groundwater will flow from the stream bank and/or bottom where the groundwater flow channel intersects the stream channel. At this point a concentration and dose will be computed. This contamination will mix with stream water and be diluted as it flows along the stream course. Finally, concentration and dose will be computed for the uranium-bearing water as it exits the basin at the outlet. Contaminated groundwater can leak through the confining bed into the Floridan aquifer. No quantitative data is available to accurately calculate this dose; it will be very conservatively estimated.

6. VOLUMETRIC DILUTION RATIOS

A volumetric dilution model for the groundwater pathway to the Bull Creek basin outlet is very simple because of the uncomplicated hydrogeology and the near absence of surface runoff. The model is depicted in Figure E-11. The V parameters reflect volumes (annual) of water received at or before the indicated discharge point. The A parameters are areas receiving precipitation, and P is precipitation.

If precipitation assumed is on an annual basis assumed to be uniform over the drainage basin, then the ratios of relative basin areas:

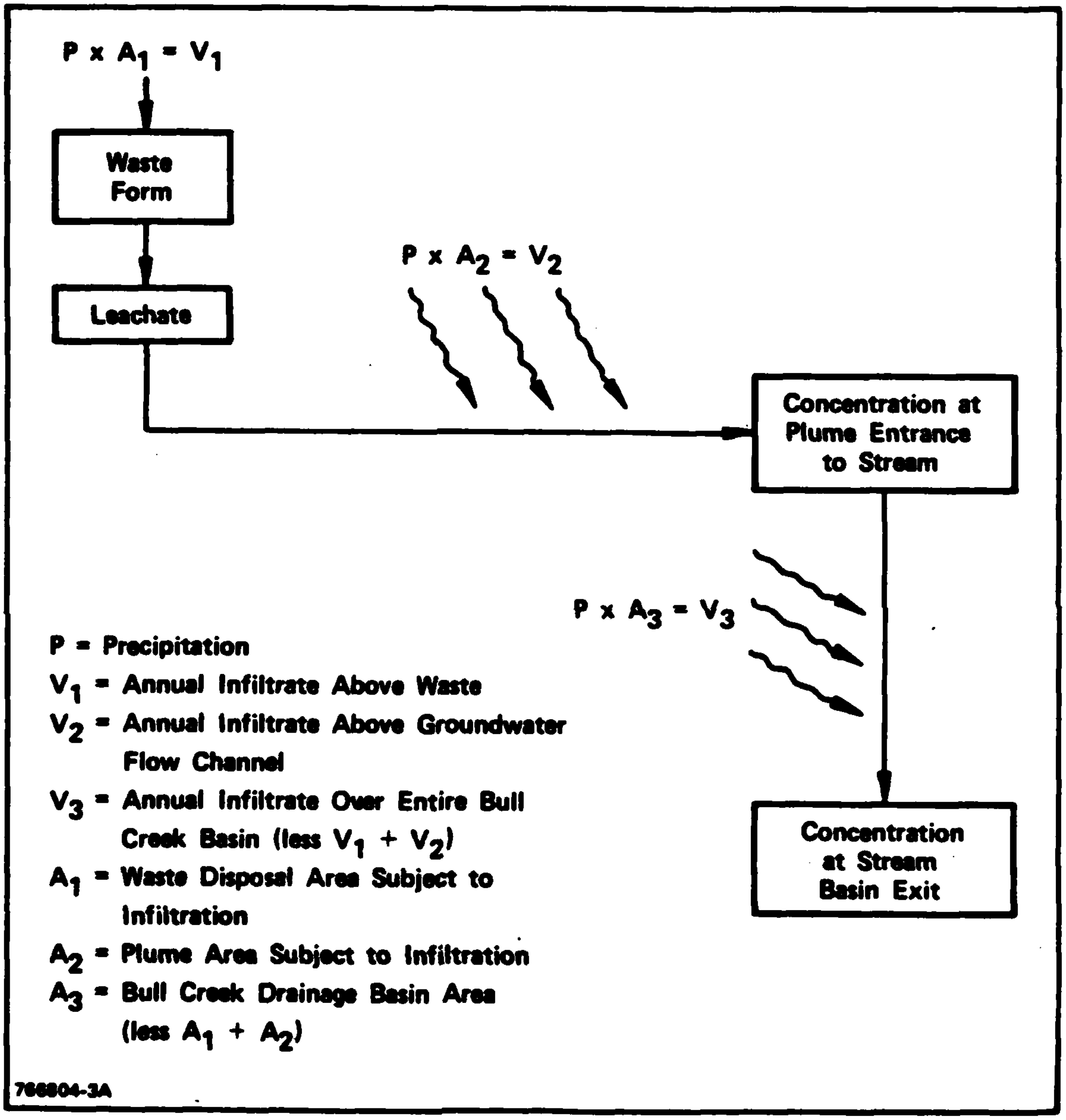


Figure E-11. Groundwater Pathway Release Model

$$\frac{A_1}{A_1} : \frac{A_2}{A_1} : \frac{A_3}{A_1} :$$

can be used as dilution factors. These ratios are expressed numerically for Bull Creek Basin as: 1:13.9:1533.

The concentration of uranium in the sand and gravel that can seep through the clay confining layer can, at worst, be equal to the concentration of uranium in the contaminated water where it enters the confining bed. The concentration on the top side of the confining layer could be as high as the leachate concentration, but will decrease as the uranium concentration in the plume in the sand and gravel aquifer decreases. Conservatively, the leachate concentration will be used to estimate a dose maximum that would come from consumption of water from a Floridan aquifer well screened to produce from the zone immediately beneath the confining layer area which is leaking contaminated water from the sand and gravel aquifer. This does estimate, as the others, does not take credit for sorption by clay. Any dispersion of the contaminated in the Floridan aquifer as the contaminatnt migrates would reduce the level but the amount of that reduction cannot be predicted herein.

The down gradient and down stream computed uranium concentration values based on leachate concentrations computed with the uranium release model are given in Table E-7. Following down the first column of that table, the average leachate concentration (from Table E-6) is divided by 13.9 and 1533 to calculate the concentrations at Stream Bank Discharge and Bull Creek Basin Outlet, respectively.

TABLE E-7. URANIUM CONCENTRATION AT VARIOUS POINTS ON THE RELEASE PATHWAY

		Control Method	
		Uranyl Hydroxide (mg/l)	Uranyl Carbonate (mg/l)
(1)	Solubility limit mg/l	0.68	2930
(2)	Average Concentration in Leachate	1.15×10^{-6}	4.94×10^{-3}
	Concentration at:		
	Stream Bank Discharge	8.27×10^{-8}	3.55×10^{-4}
	Bull Creek Basin Outlet	7.50×10^{-10}	3.22×10^{-6}
	Water Well in Floridan Aquifer(3)	1.5×10^{-6}	4.94×10^{-3}

(1) Based on W# 222.

(2) Returned from computer source term model see Tables 6 and 7.

(3) Well, cased to yield from the hypothetical "zone-of-contamination" immediately below the clay confining layer. The concentration is the same as the leachate concentration.

7. DOSE ASSESSMENT

In this section a dose that is likely to result from the chronic ingestion of uranium in a 50-year consumption, 50-year body burden scenario will be calculated. This dose is utilized because it represents a conservative evaluation of the exposure to a person if they consumed water for 50 years with any of the six uranium concentrations shown in Table E-7.

Table E-8 presents a summary of the dose calculations. The data are presented in two sections. The first section requires groundwater chemistry whereby uranium concentration is limited by formation of uranyl hydroxide. The second section requires groundwater chemistry whereby uranium concentration is limited by formation of uranyl carbonate and several related complex ions. Within each section, the first row contains concentrations and dose assessments for actual in-trench area leachate and the Floridan well, the second row for the groundwater as it discharges through the bank into the stream, and the last row for the stream water at Bull Creek Basin outlet.

The columns in the table take the mg/l uranium concentration and transform it into a dose. The factors used in the calculations and their sources are indicated on the bottom of Table E-8. No dose even at the leachate level exceeds 25 mr/yr, the applicable 10CFR61 release standard. The 10 CFR 20.302 standard from Appendix B is 4×10^{-5} μCi/ml for water release. This converts to 0.12 mg/l, and the highest calculated leachate concentration is nearly two orders-of-magnitude less than that value.

TABLE E-8. 50-YEAR WHOLE BODY EQUIVALENT EXPOSURE

	Concentrations mg U/L	Uranium mg/yr/ Person	Uranium gm/yr/ Person	Uranium mCi/yr/ Person	rem/Year/Person Kidney	rem/Year/Person Red Marrow	rem/Year/Person Endosteal	rem/ 50 Year/ Person Kidney	rem/ 50 Year/ Person Red Marrow	rem/ 50 Year/ Person Endosteal	Whole Body Equivalent/ 50 Yr Exposure/ Person
HYDROXIDE CONTROL											
Average Leachate Concentration	1.15E-06	8.40E-04	8.40E-07	2.80E-07	1.68E-06	2.12E-07	3.08E-06	4.19E-05	5.31E-06	7.69E-05	1.55E-05
Stream Bank Discharge Concentration	8.27E-08	6.04E-05	6.04E-08	2.01E-08	1.21E-07	1.53E-08	2.21E-07	3.02E-06	3.82E-07	5.53E-06	1.12E-06
Bull Creek Outlet Concentration	7.50E-10	5.48E-07	5.48E-10	1.82E-10	1.09E-09	1.39E-10	2.01E-09	2.74E-08	3.46E-09	5.01E-08	1.01E-08
CARBONATE CONTROL											
Average Leachate Concentration	4.94E-03	3.61E+00	3.61E-03	1.20E-03	7.21E-03	9.13E-04	1.32E-02	1.80E-01	2.28E-02	3.30E-01	6.67E-02
Stream Bank Discharge Concentration	3.55E-04	2.59E-01	2.59E-04	8.63E-05	5.18E-04	6.56E-05	9.49E-04	1.29E-02	1.64E-03	2.37E-02	4.79E-03
Bull Creek Outlet Concentration	3.22E-06	2.35E-03	2.35E-06	7.83E-07	4.70E-06	5.95E-07	8.61E-06	1.17E-04	1.49E-05	2.15E-04	4.35E-05

Concentrations mg U/L	Uranium mg/yr/ Person	Uranium gm/yr/ Person	Uranium mCi/yr/ Person	rem/Year/Person (Kidney, Red Marrow, Endosteal)	rem/ 50 Year/ Person (Kidney, Red Marrow, Endosteal)	Whole Body Equivalent/ 50 Yr Exposure/ Person
↑ x 730	↑ x 10-3	↑ x 0.333 mCi/gm	↑ x DCF rem/mCi(2)	↑ x25(4)	↑ Σ(.3K + .12 RM + .03 END)(3)	

(1) Assume 730 L/yr water consumption per person and U-238 activity 0.333 mCi/gm.
(2) Dunning, D. E., et al., "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring.
(3) ICRP, Pub 26, Vol. 1, No. 3, 1977.

(4) $\frac{n(n+1)}{2}$ ÷ 50, to approximate continuous exposure per person for 50 years.

8. SUMMARY AND CONCLUSIONS

The summary and conclusions of each subsection of this document are highlighted below, and the overall conclusion is presented at the end of this section.

a. Uranium Toxicology

(1) Summary: Background information indicates that one must consume in the neighborhood of 700 ppm dissolved uranium in water to cause toxic metal poisoning symptoms. Long term doses may become radiologically significant above 10 ppb uranium in water taken into the body.

(2) Conclusion: Chemical toxicity is a short term problem for higher uranium concentrations, while radiotoxicity is a longer term problem which can be caused by prolonged exposure to lower uranium levels in water.

b. Physiography, Climate, Hydrogeologic Setting, Hydrology and Hydrogeology of the Potential Site

(1) Summary: Three wells were examined because their setting (physiographic, etc.) is similar to a well which could be drilled to yield water from the sand and gravel aquifer at TAC64. The

water table in this well would be about 80 feet beneath the surface. The head or piezometric surface of the underlying Floridan aquifer is near the top of the Pensacola clay unit which separates the sand and gravel aquifer from the Floridan aquifer. Because of the nature of the soil and the terrain, overland runoff is a very small fraction of the total discharge and occurs in valley slope areas with abundant clay content in the soil.

(2) Conclusion: Low-levels of uranium may leach from the waste and travel down to the water table and the present position of the piezometric surface for the Floridan aquifer would permit recharge from the sand and gravel system into the Floridan aquifer at that location. Since the high soil hydraulic conductivity in the vicinity of the proposed site and soil conditions in general minimize surface runoff, the surface water release pathway is not a significant one and is not examined.

c. Equilibrium Geochemistry and Uranium Speciation

(1) Summary: Because dissolved oxygen (or Eh) data were unavailable, some tentative values were assumed, and stability of various uranium species was examined. The choice of oxidation reduction potential (Eh) can clearly shift the system from UO_2 to UO_2^{+2} areas of stability. Movement from a field of UO_2^{+2} stability to a field of UO_2 stability should not be assumed to fix the uranium because reduction kinetics are poor. With stability assumed for uranyl ion or uranyl carbonate complexes, uranium solubilities with either carbonate or hydroxide control were calculated.

(2) Conclusion: The water chemistry in one of the three wells would support chemical and radiologically significant doses in a carbonate-controlled system. The chemical environment of two wells will support uranium concentrations that exceed the threshold of significance for long term radiological doses (10 ppb). Thus the geochemical environment cannot be depended

on to prevent or curtail the migration of uranium away from the waste burial site.

d. Release Scenario/Source Term

(1) Summary: Traditional leaching data is unavailable for uranium. If it were available, leaching data would not be applicable because of the site conditions at Eglin AFB. A computer model based on equilibrium-controlled dissolution of uranium from a concrete waste form was envisioned. The model uses the hydraulic conductivity of concrete and the soil to determine residence times for water among and within the waste forms. The model defines a concentration of uranium in the fluids leaving the waste-form array and projects the uranium fraction removed from the waste forms as a function of time.

(2) Conclusion: The highest calculated leachate concentration with the maximum depleted uranium concentration disposal option under 10CFR20.302 (for carbonate-controlled solubility) is about 5 ppb. At that rate 13% of the total uranium in the waste will be

released in 10^6 years. The model is thought to provide a more realistic estimate of uranium release than a conventional leaching model.

However, the model is very conservative because it omits consideration of the high density polyethylene (HDPE) barrier around the concrete wasteform.

e. Pathway Analysis

(1) Summary: Because of the high infiltration rate and the simplicity of the sand and gravel hydrogeologic system, the dilution factor approach provides a simple and conservative means to estimate stream bank discharge water quality and basin outlet water quality. To add to the conservatism, sorbtion and dispersion are not considered in the analysis.

(2) Conclusions: The concentrations of uranium, with carbonate solution control assumed, are approximately 0.4 ppb and 3×10^{-3} ppb at the stream bank discharge point and the basin outlet point, respectively. These concentrations

are at least 10 times less than any known or proposed standard. The conservative concentration maximum for uranium in a Floridan aquifer well is 5 ppb.

f. Dose Assessment

(1) Summary: Doses are calculated for the highest calculated uranium concentrations under hydroxide- and carbonate-controlled scenarios. The doses are listed for leachate of Floridan aquifer well, stream discharge and basin discharge. The doses are 50 year ingestion/carried as body burden for 50 years.

(2) Conclusion: The highest doses were for the carbonate-controlled scenario. The calculated WBE exposures were approximately 67 mrem, 5 mrem and 4.4×10^{-2} mrem for leachate, stream bank discharge and basin outlet waters, respectively. No calculated dose, even from leachate of Floridan aquifer well, exceeds the 25 mrem/year standard for waste release under 10CFR61. No dose exceeds the 10CFR20.302 Appendix B standard for release.

In closing, it should be said that although the terrain in Florida poses difficulties for ordinary shallow-land disposal of waste, a carefully designed, properly engineered disposal effort will have no significant impact on the groundwater in the area.

REFERENCES

E-1. Hodge, H. C. and Voegtlin, C., "Pharmacology and Toxicology of Uranium Compounds," McGraw-Hill Book Co., Inc. 1949.

E-2 Friberg, L., Bordberg, G. F. and Vouk, V. B., "Handbook on the Toxicology of Metals," Elsevier/North-Holland Biomedical Press, 1979.

E-3. Casarett and Doull, "Toxicology: The Basic Science of Poisons," MacMillan Publishing Co., Inc. 1980.

E-4. Anon, "Soils and Groundwater Conditions at Two Borrow Pits Eglin Air Force Base," prepared by Water and Air Research, Inc., Gainesville, Florida, April 1983.

E-5. Crews, R. C., et. al., "Water Quality: Streams and Ponds on Selected Test Areas on Eglin Air Force Base, Florida," AFAL, AF Systems Command, USAF, Eglin AFB, Florida, May 1977.

E-6. Barr, D. E., Maristany, A. and Kwader, T., "Water Resources of Southern Okaloosa and Walton Counties, Northwest Florida," Northwest Florida Water Management District Water Resources Assessment 81-1.

E-7. Pourbaix, M., "Atlas of Electrochemical Equilibrium in Aqueous Solutions," National Association of Corrosion Engineers, Houston, TX, Cebelcor, Brussels, 1974.

E-8. Semmler, R. A., "Final Report on XRD Analysis of U Bearing Powders," prepared under Contract #F0865181 M1530 for AFAL, Eglin AFB by IIT Research Institute, 10 West 35th St., Chicago, IL 60616.

E-9. Garrels, R. M. and Christ, C. L., "Solutions, Minerals and Equilibria," Freeman, Copper & Co., Stockton, CA 1965.

E-10. Langmuir, D., "Uranium Solution-Mineral Equilibria at Low Temperatures with Applications to Sedimentary Ore Deposits," Geochem, et. Cosmochim, Acta, V. 42, pp. 547-569.

E-11. Dam, W. L., Discussions at meeting with U.S. NRC, M5 623-55 in Washington, D.C. 20555 on November 5, 1984.

E-12. Krauskopf, K. B., "Introduction to Geochemistry," McGraw Hill Book Co., 1979.

E-13. Kennedy, L. R., "Rainfall Summary for the Northwest Florida Water Management District," Northwest Florida Water Management District, Water Resources Special Report 82-3.

E-14. Freeze, R. A. and Cherry, J. A., "Groundwater," Prentice-Hall, Inc., Englewood Cliffs, NJ 07632, 1979.

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